THE OHIO STATE UNIVERSITY
ADVANCE ENERGY VEHICLE DESIGN PROJECT

LAB MANUAL

THE OHIO STATE UNIVERSITY
COLLEGE OF ENGINEERING

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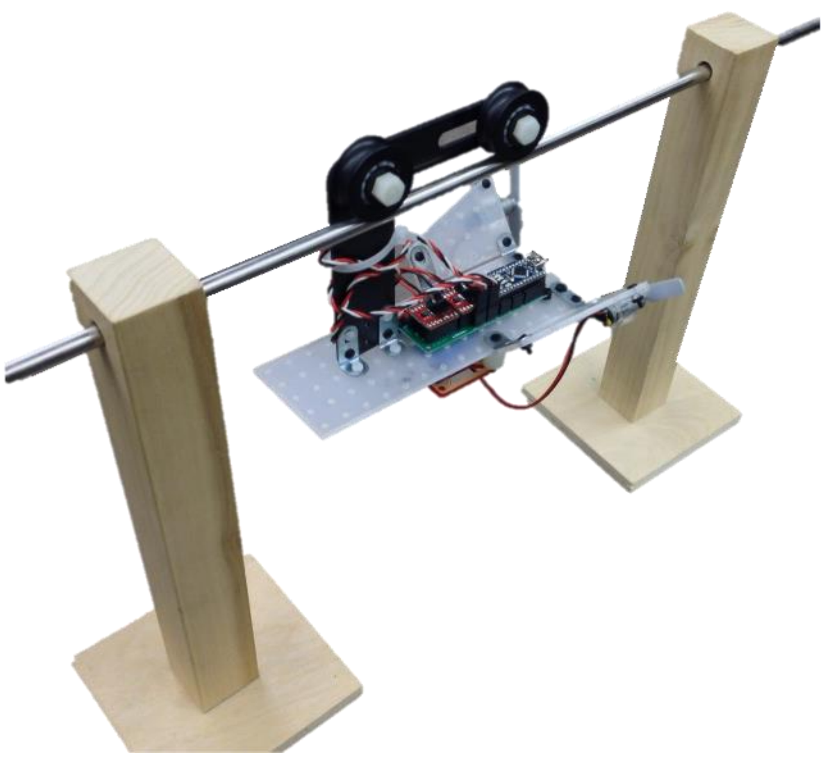
Created by:
Dr. Clifford Whitfield
Assistant Professor of Practice (Whitfield.22@osu.edu)

Dustin West
Graduate Research and Teaching Associate (West.425@osu.edu)

Jacob Allenstein
Graduate Research and Teaching Associate (Allenstein.1@osu.edu)

THE OHIO STATE UNIVERSITY
ENGINEERING EDUCATION INNOVATION CENTER
244 HITCHCOCK HALL, 2070 NEIL AVENUE, COLUMBUS, OH 43210

Table of Contents



The AEV Project: Lab Overview

Introduction

The Advance Energy Vehicle (AEV) design project is a team-based project that introduces concepts of project management and teamwork, the design process, and project documentation. AEVs are small (<500 grams), autonomous, electric motor-powered, propeller-driven vehicles that are suspended from and maneuver along a monorail track systems hung from the laboratory ceilings, see Figure 1 for example. The AEV structure is constructed with components provided in a lab kit which includes pre-fabricated PVC sheet structure, monorail wheels, electric motor(s), propeller(s) and an in-house built AEV- Autonomous Control System with externally mounted and adaptable sensors for feed-back control. AEVs are designed based on a series of labs and performance tests that utilize wind tunnels and cover topics such as electric motor and air-breathing propulsion performance, system efficiency, automatic control programming, and energy management in completing the operational objectives provided.

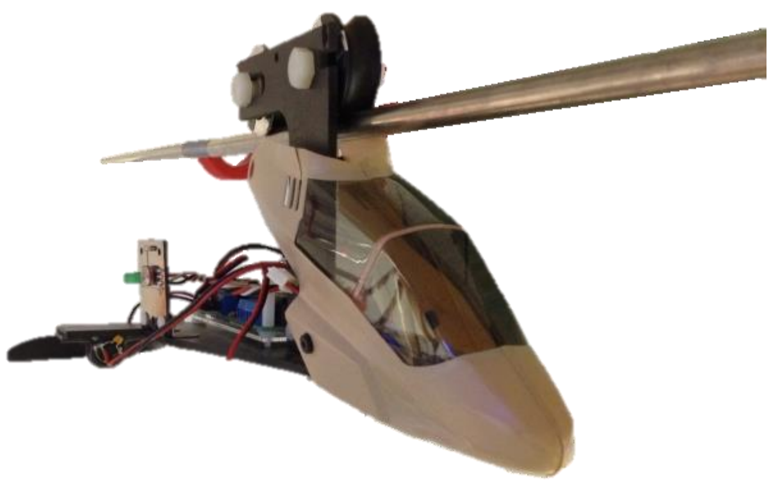


Figure 1: AEV Example (Night-Hawk)

Lab Objectives

The AEV design project consist of three main objectives:

1. *Project Management and Teamwork* - Project management and teamwork throughout the design process is regularly evaluated by requiring an updated project portfolio and team working agreement. Each team tracks and manages the design-build project through portfolio records that contain initial concepts, brainstorming notes, delegation of tasks, laboratory team executive summaries and memos, and weekly performance test summaries. The final AEV designs are evaluated during individual competitions and scored based on performance and design criteria. At the end of the project a final report

is submitted and a PowerPoint presentation is developed to present the teams' work to the class.

2. *Design Process* - The design process consists of the following:
    a. Identifying the project requirements and constraints.
    b. Gathering background information.
    c. Brainstorming initial concepts.
    d. Identification of management of materials.
    e. Preliminary analysis and initial design.
    f. The build/test/modify/document cycle.

A schematic of the AEV process is shown in Figure 2

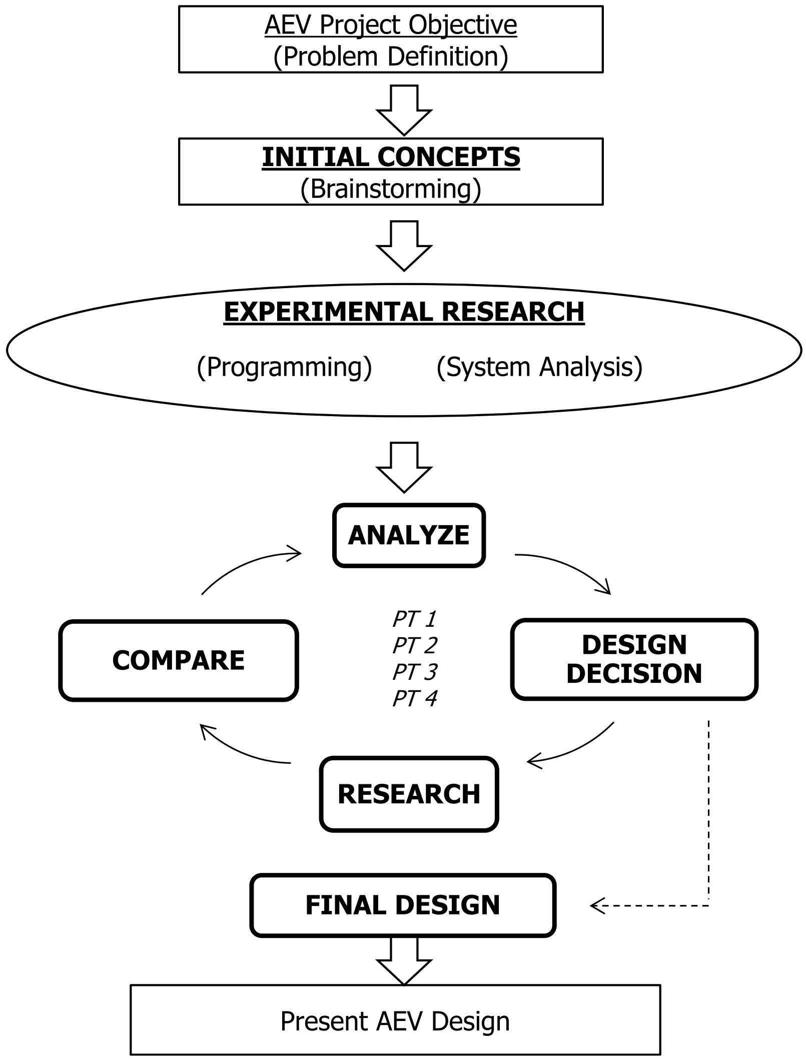


Figure 2: AEV Design Process

3. *Project Documentation* – Project documentation for the AEV design project includes three parts:
   a. Project Portfolio - The team shall maintain an electronic project portfolio and keep a complete record of the work that the team has done to create the final AEV product. The project portfolio should include all related documentation from the beginning of the semester until the completion of the project.
   b. Midterm and final written report - The team will provide a preliminary (midterm) and critical (final) design review of all aspects of the design process.
   c. Oral Presentation - The team will develop and give a PowerPoint presentation of the AEV design experience.

AEV Showcase (Spring Semester Only) – The AEV showcase is an event where teams from all different classes can display their work and be judged for various engineering design awards.

Table 1: Important Acronyms

Acronym	Meaning	Definition
AEV	Advance Energy Vehicle	Small, Autonomous, electric, motor-powered, propeller-driven vehicle
CDR	Critical Design Review	End of semester progress report summarizing the entire semester
LPQ	Lab Proficiency Quiz	Lab quiz to test students' knowledge on everything AEV
MCR	Mission Concept Review	It specifies the mission objectives and detailed specifics
PDR	Preliminary Design Review	Midterm progress report summarizing the AEV design up until Lab 08
PT	Performance Test	The labs post-LPQ in which students have one task to complete per week
TRR	Test Readiness Review	Small memo document to describe the week's load and how it will be distributed amongst the team

Lab Safety Rules

The guidelines that must be followed at all times in the lab are as follows:

1. ALWAYS get circuit and program verified by instructional staff prior to plugging in the power.
2. Do not stand in the propeller's plane of rotation.
3. Do not put your finger in the propeller.
4. No dangling jewelry or loose clothes.
5. No 'open' shoes. Close-toed shoes or boots only.
6. No climbing or standing on chairs or tables.
7. Be aware of sharp corners and edges which may exist on tables or on apparatus and tools.
8. Always know the location of the phone and of the first-aid kit.
9. Report to the instructor ALL injuries occurring during lab.
10. ALWAYS FOLLOW THE PROPER TESTING PROCEDURE

Failure to follow these rules and guidelines may result in losing lab privilege with loss in lab participation grade for the course.

Testing Procedure

The following outlines the testing procedure for AEV operation on the track to minimize the potential of damaging the AEV, AEV components, and YOU.

AEV Desktop-track Setup and Controller Software Confirmation

- Each AEV must demonstrate proper balance on the desktop track with the AEV center-of-gravity in between and directly below the two monorail track wheels.
- The vertical support arm must be equal to or less than 6 inches from the monorail track.
- IF major changes are made to the AEV Controller Software in between runs, confirmation of the desired programmed power control must be checked statically on the desktop track prior to testing on the classroom track.
- The AEV power must be off when transferring AEV from the desktop to the classroom track.

AEV Classroom-track Testing Procedure

1. AEV power OFF.
2. A team member must be at each station.
3. Teammate #1 takes the AEV to the Beginning/Starting Point.
4. All other teammates must be at their designated stations and be prepared to stop the AEV if it does not pass the required operation procedure in designated location.*
5. Inform classmates (if in operational area) that AEV operation is going to start.
6. Teammate #1 sets AEV on the monorail track and turns AEV power on.
7. Receive confirmation from all other Teammates that they are ready.
8. Begin AEV operation by pressing the AEV Automatic Control System start button.

*The Teammate must place their hand above the track at of the designated stopping area.

AEV Operation Pass/Fail Conditions

- If the AEV stops within the designated stopping area, the vehicle passes the required operation stopping procedure.
- If the AEV stops prior to the designated stopping area the AEV does not pass and MUST be stopped by grabbing the AEV's monorail track wheels.
- If the AEV continues through the designated stopping area (without stopping at all), the AEV MUST be stopped by grabbing the AEV's monorail track wheels at the end of the designated stop and turning the power switch off.

Lab Calendar

2015-2016 AEV Project Schedule (Engineering 1182 / 1188)					
Topic	No.	Title	Points Available	Assigned Date	Due Date
Labs	1	Creative Design Thinking	80	Lab 01	Lab 02
	2	Programming Basics	80	Lab 02	Lab 03
	3	Concept Screening & Scoring	80	Lab 03	Lab 04
	4	External Sensors	80	Lab 04	Lab 05
	5	System Analysis 1	95	Lab 05	Lab 06
	6	System Analysis 2	95	Lab 06	Lab 07
	7	Design Analysis Tool	55	Lab 07	Lab 08A
	8	Lab Proficiency Quiz (LPQ)	100	Lab 07	Lab 07
Test Readiness Reviews (TRR)	1	Performance Test 1 - TRR	55	Lab 07	Lab 08A
	2	Performance Test 2 - TRR	55	Lab 08C	Lab 09A
	3	Performance Test 3 - TRR	55	Lab 09C	Lab 10A
Performance Test Memos	1	Performance Test 2 - Memo	100	Lab 09A	Lab 10B
	2	Performance Test 3 - Memo	100	Lab 10A	Lab 11B
Design Reviews	1	Preliminary Design Review	200	Lab 07	Lab 09B
	2	Critical Design Review	200	Lab 09A	Lab 12C
Final Documentation	1	Project Portfolio	100	Lab 01	Lab 12C
	2	Oral Presentation Draft	25	Lab 07	Lab 10C
	3	Oral Presentation	100	Lab 07	Lab 12 B/C
Quizzes	1	Quiz 1	5	Lab 00	Lab 01
	2	Quiz 2	5	Lab 01	Lab 02
	3	Quiz 3	5	Lab 02	Lab 03
	4	Quiz 4	5	Lab 03	Lab 04
	5	Quiz 5	5	Lab 04	Lab 05
	6	Quiz 6	5	Lab 05	Lab 06
Bonus	1	Bonus Video Part 1	50	Lab 00	Lab 07
	2	Bonus Video Part 2	200	Lab 00	Lab 12C

* This schedule is subject to change based on instructor discretion

** See Course Syllabus to see grade percentages and distribution

Mission Concept Review (MCR)

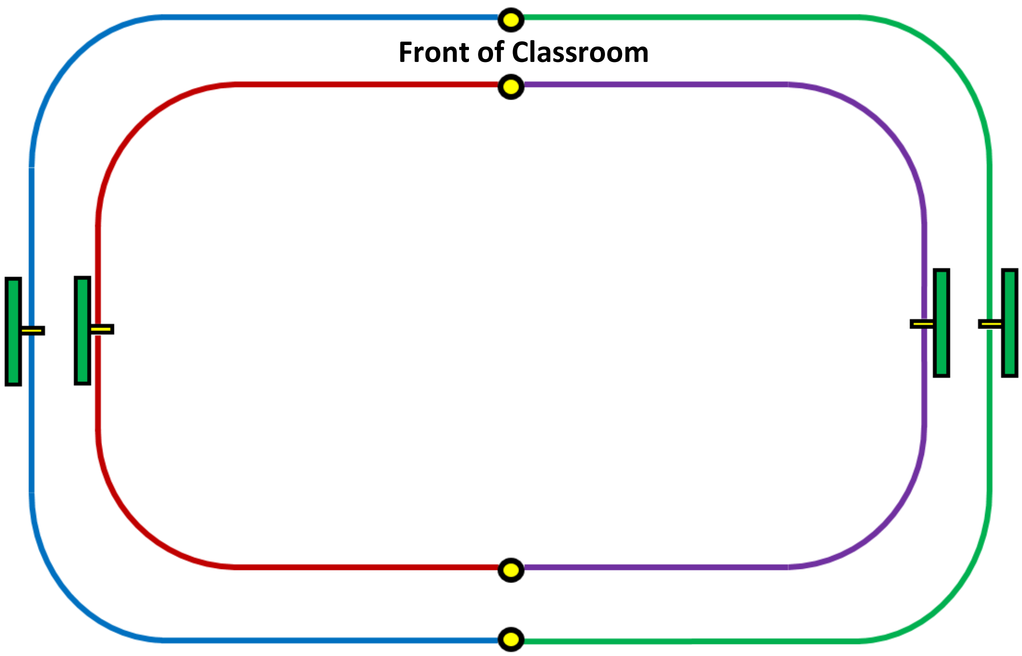
Background

The galactic empire is rebuilding their army after the destruction of the Death Star. The rebel alliance needs to prepare for war on remote planets to ensure that the galactic empire is unaware of operations. Due to being on remote planets, power is very limited. The alliance is looking for a monorail network system to transport their R2D2 units which are constructed on one side of the land to where the interceptor aircrafts are being assembled through the means of a green, energy efficient, and cost effective system. The need for an energy efficient system, like an Advance Energy Vehicle (AEV), is due to the base being located on a remote planet where power is a luxury.

Mission Objectives

The scaled transport-AEVs will focus on *energy management*, *operational efficiency* and *operational consistency*. Energy used per mass of the AEV will be measured and recorded during AEV operation. The goal is to successfully pick up and deliver precious cargo stored on a caboose while meeting the operational requirements, design constraints and minimizing the energy/mass ratio. Due to the planet being remote and unstable, the monorail may have slight variations over time due to the planets shifting faults, therefore, the AEV should be not depend on a specific track. The AEV should have operational consistency in which the AEV performs consistently regardless of type of cargo (cargo should not fall off track) or power supplies (battery). As contractors, it is the goal to create a model scale AEV to perform the Scenario in which the team will defend their final product to the rebel alliance (instructional staff: Instructor, GTA, and UTA's). The top three performing and creative AEV's will go on to the AEV Showcase (SPRING Semester 2016 only) to compete for prizes and the overall goal of obtaining the contract for construction of the AEV design.

Monorail Network Description



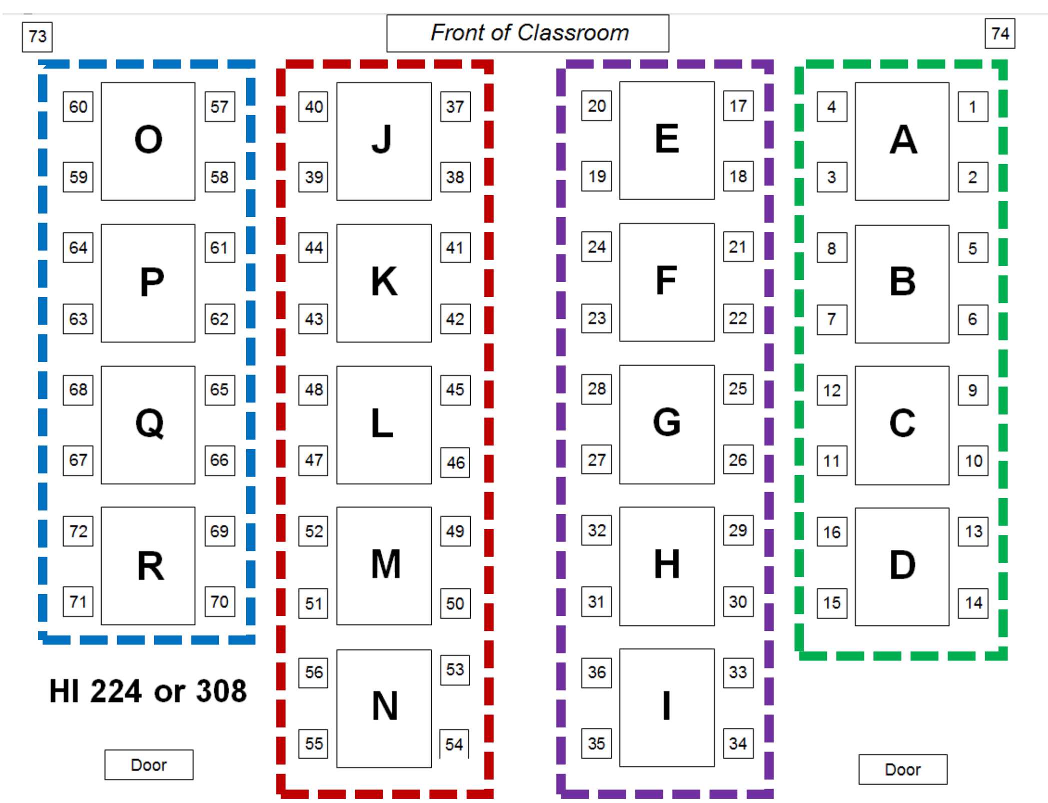


Figure 3: Classroom division of track layout

The class is split up into four different rows which will use the specified section of the track (see Figure 3). The colored box represents the color section of the track as seen in Figure 3. Tables A-D will have the outside track on the right side of the classroom (facing the front of the classroom) where tables E-I will have the inside, right side of the track. Tables J-N will have inside left side of the track and finally tables O-R will have outside left side. This layout is subject to change based on instructor's discretion and the class size.

AEV Operational Requirements

The scaled transport-AEV must complete the following scenario while minimizing the energy/mass ratio. The team will only have half the track to utilize. The scenario is the following and is highlighted in Figure 4, Figure 5, and Figure 6:

1. Start at the Drop-off area (see Figure 4) with the front wheel of the AEV just behind Mark 1.
2. The AEV will traverse to the gate to be checked in.
    a. To successfully get through the gate the AEV must trip (pass by) the first sensor only. This is the blue sensor in Figure 5. Once the sensor has been activated, it takes the gate 7.0 seconds to open. If the AEV gets too close to the gate and trips the red sensor the gate will lock and the AEV will not be granted permission to pass through the gate.
3. Navigate to the cargo area (see Figure 6).
4. Stop at the cargo area and pick up an R2-D2 and wait 5.0 seconds to verify cargo is all loaded.
5. Travel back to the gate.
    a. To successfully get through the gate the AEV must trip (pass by) the first sensor only. This is the blue sensor in Figure 5. Once the sensor has been activated, it takes the gate 7.0 seconds to open. If the AEV gets too close to the gate and trips the red sensor the gate will lock and the AEV will not be granted permission to pass through the gate.
6. Traverse to the drop-off area. To successfully complete the mission objective, both wheels of the AEV must be between Mark 2 and the start point (Cargo does not have to be within these two marks.).

Note: The scaled transport-AEV must complete the circuit within 2.5 minutes. The cargo is fitted with a small magnet (see Figure 6). There needs to be a clearance of a minimum of 2 x 2 inches between the magnet and the Arduino board. The AEV must fit in the plastic bin that it was issued in (the plastic wheel arms can be discounted along with propellers).

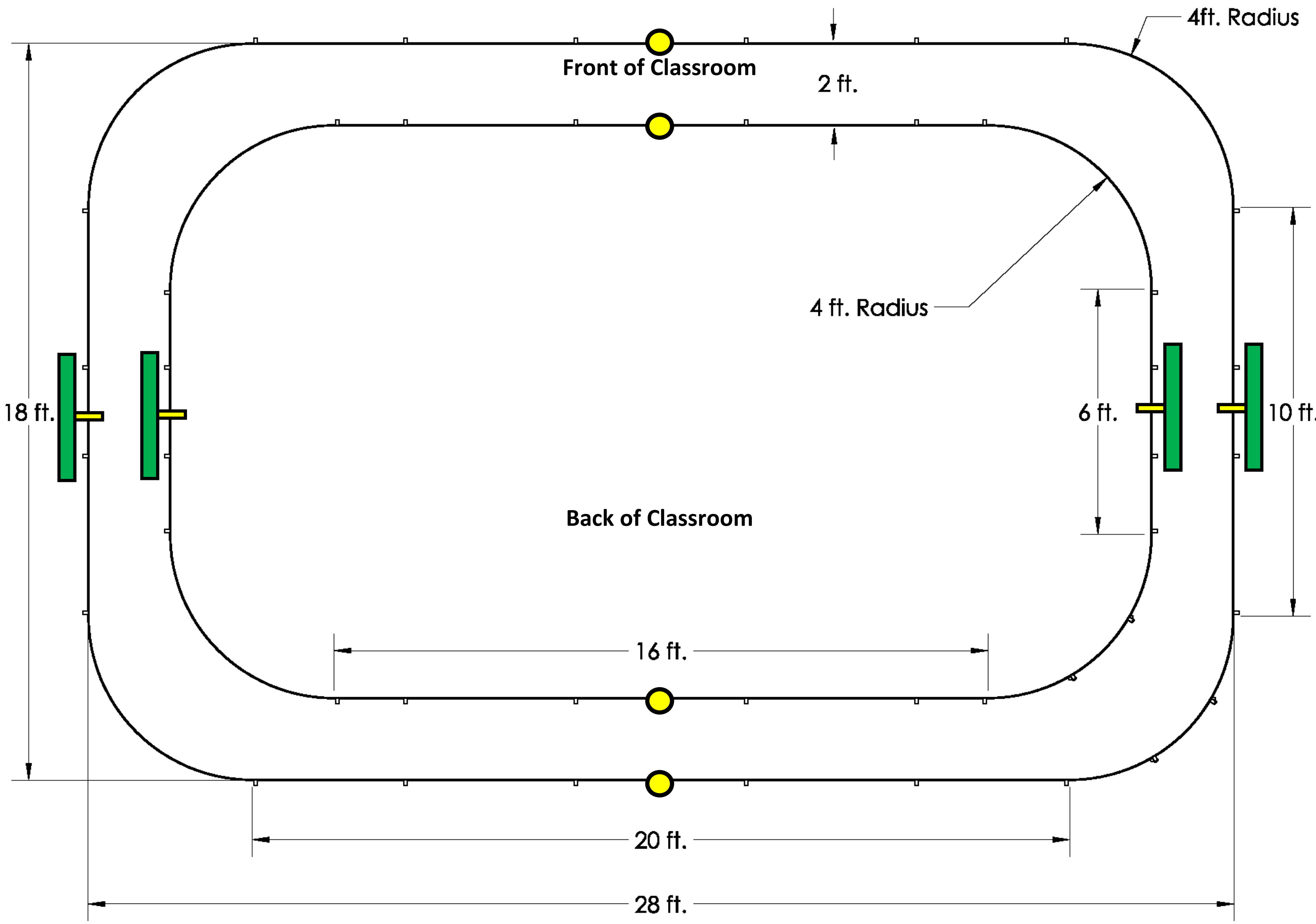
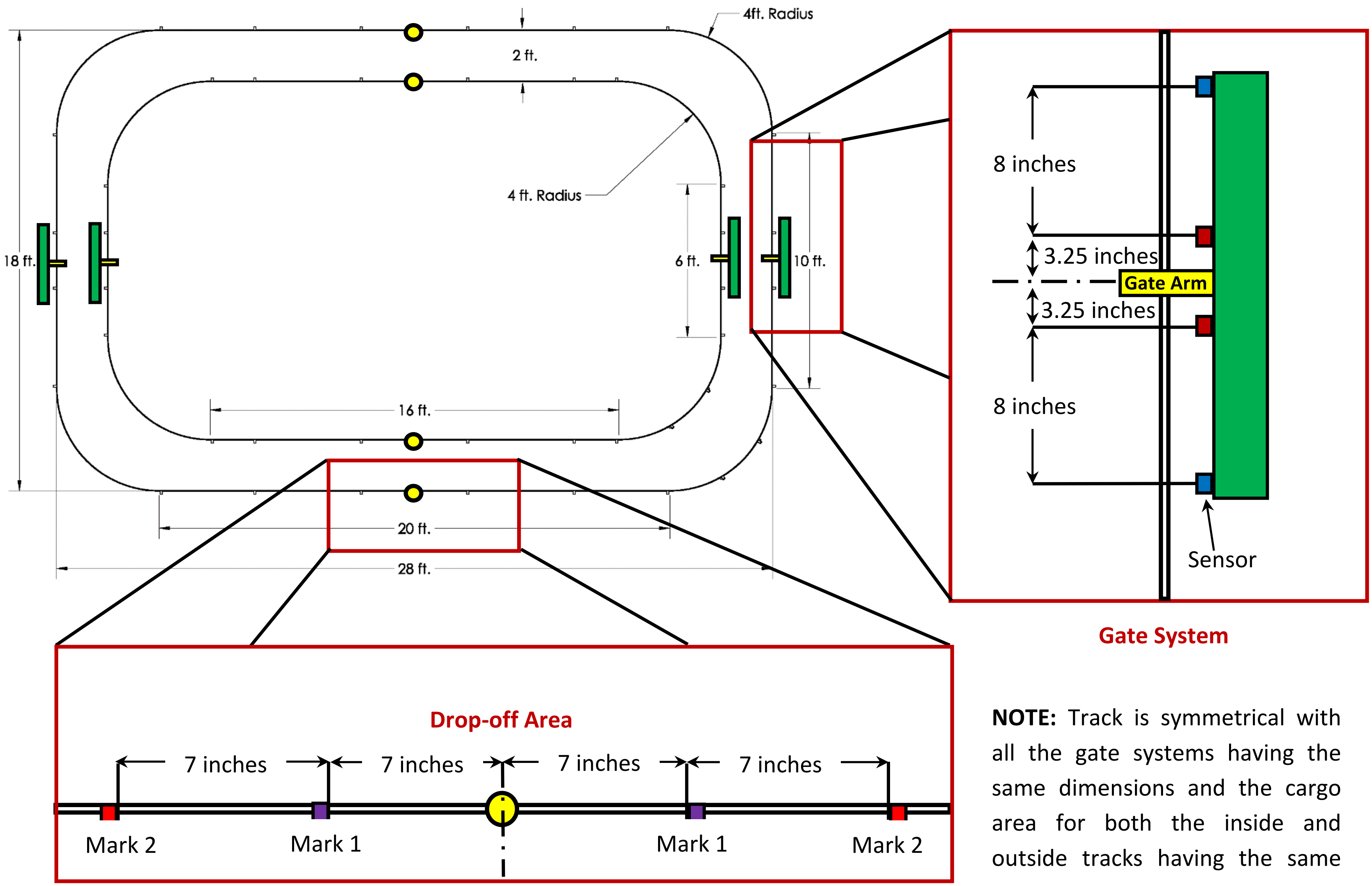
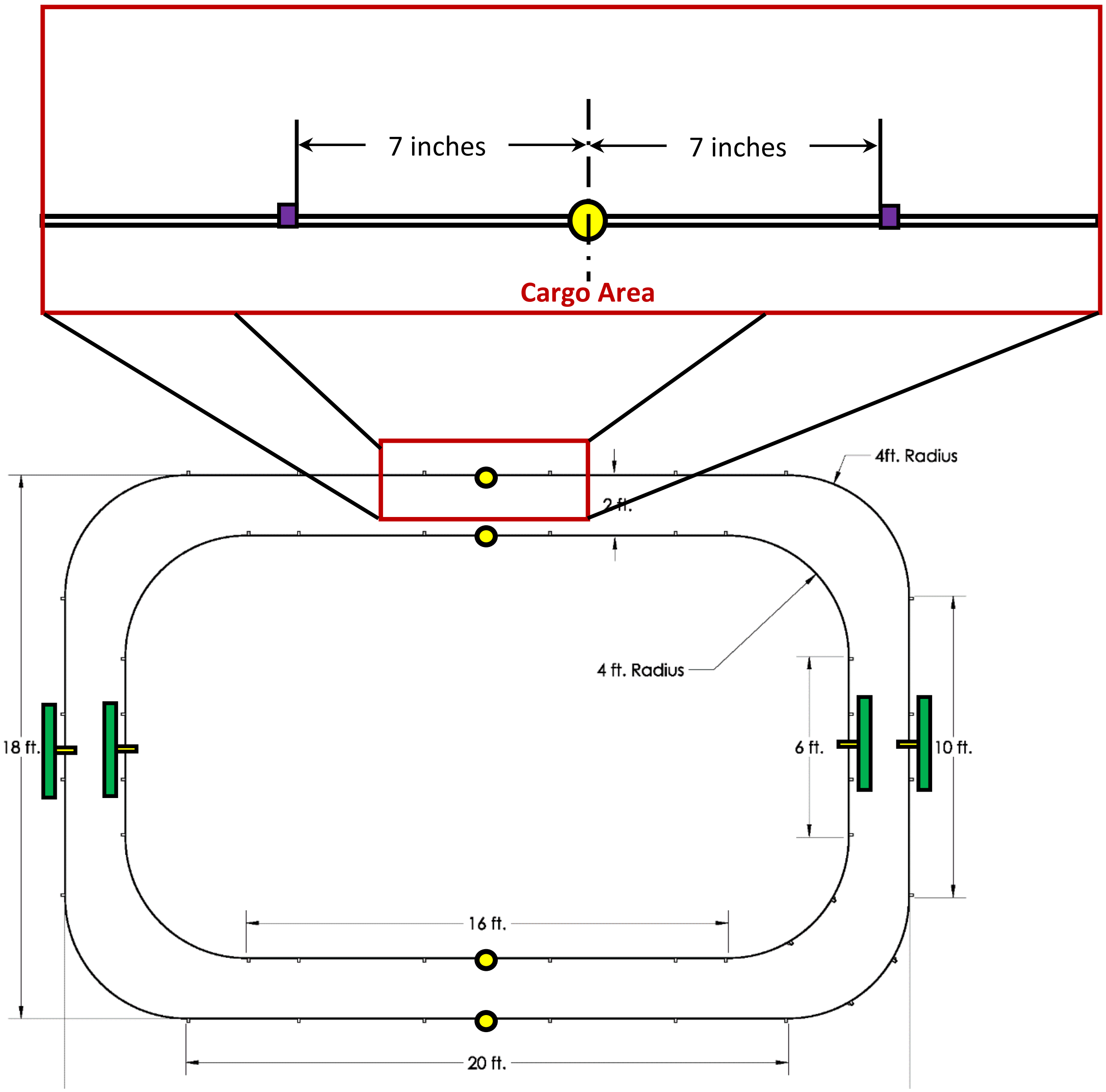


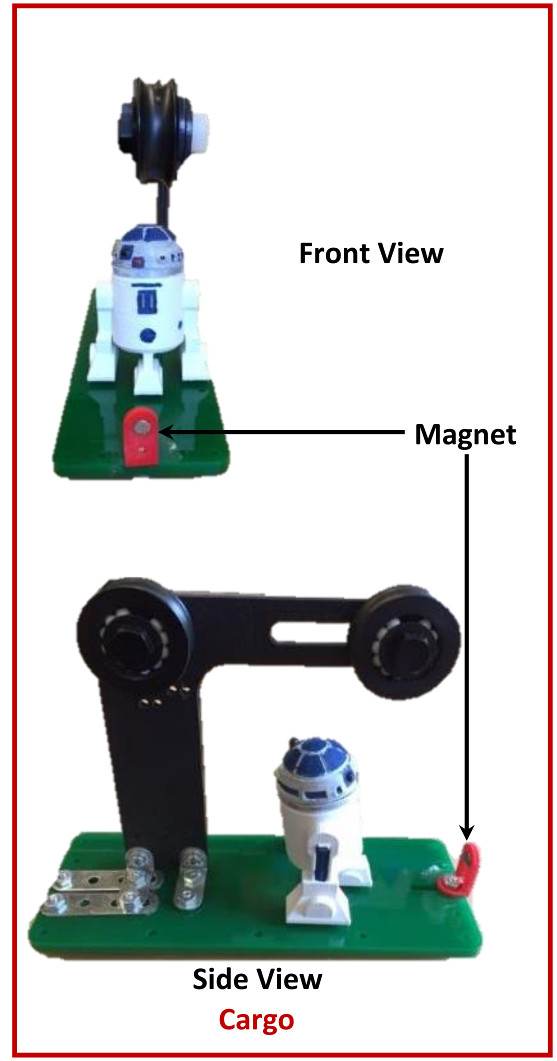
Figure 4: AEV Track Layout



NOTE: Track is symmetrical with all the gate systems having the same dimensions and the cargo area for both the inside and outside tracks having the same

Figure 5: AEV Track Layout Beginning and Gate Specifics





Cargo Specifications

Weight: 220 $\pm$ 5 grams

Dimensions: 2.75 x 7.5 x 5.5 inches (W x L x H)

Figure 6: AEV track layout cargo area and cargo

Lab 01: Creative Design Thinking

Objectives

1. Learn two techniques used for creative design thinking.
2. Become familiar with obstacles to creativity.
3. Become familiar with the components in the AEV kit.
4. Learn the basic of orthographic drawings.
5. Brainstorm on individual AEV concept sketches.

Lab Equipment

1. AEV desktop stand.
2. AEV kit

Background: Creative Design Thinking

Creativity according to the Merriam-Webster dictionary is “the ability to bring into fruition one’s original, imaginative and/or expressive ideas and concepts to serve new purposes and/or fulfill a need.” Engineers use their creativity to generate useful ideas and solve problems.

The conceptualization of successful creativity consist of two processes: (1) Generating a useful idea and (2) communicating the idea. Generating a useful idea is usually achieved in two different situations.

a. In the first situation, a ***need*** exists and a ***product*** is developed to fill the need
b. The second situation would be one in which ***new technology*** gives rise to a new ***product*** and then, a need has to be created. Often this can be done with successful marketing and advertising, but it is always more risky than designing for an existing need.

There are several ways of communicating ideas. Many times people mistaken creative with artistry because the artistry is an effective means of expression. The ability to draw or sketch well can help to easily communicates one’s ideas. However, those with little or no artistic ability should not be intimidated by design. CAD software and verbal descriptions are incredibly useful tools and should not be overlooked.

Offering an aesthetically appealing product is also a large portion of helping to communicate and influence the user’s attraction to the product. Acknowledging that design is indeed a driving factor in the success of a consumer product is the first step to arriving at a strong market for a product.

Many sources provide information on how to become more creative. Some creativity aids include:

a. Study creative thinking techniques.
b. Keep a daily journal/notebook – record everything, not just project related information.

c. Indulge in relaxing activities. This helps to “free” one’s mind and permit the flow of ideas.
d. Take part in activities outside of one’s current field of study – it is very important in order to associate ideas from other applications.
e. Read! Reading allows one to increase one’s imagination and knowledge of the world.
f. Ask questions. Curiosity about one’s environment increases one’s knowledge.
g. Finally, exchanging and sharing ideas allows for the free-flow of ideas. Often the expression of different viewpoints helps to incite innovative ideas.

Just as there are many ways to help increase one’s creativity, there are also many obstacles that inhibit creativity. The list includes:

a. Fear of criticism.
b. Lack of confidence.
c. Negative stress from one’s home and work environment.
d. Environmental obstacles due to busy life-style, high pressure and hectic work environment.
e. Too much structure and rules that create barriers and limits to the flow of ideas.
f. Conflicting goals within.

These obstacles are often influenced by the environment, coworkers, or management. Within the teams it is very important to be aware of these obstacles and avoid them. There are many techniques used throughout industry to generate, use and promote creative and innovative ideas (i.e., drawing, construction, research and lateral thinking etc.). There are multiple other ways to be creative. The team is welcomed to explore these other ways as they are defined in the Appendix A – Creative Design Thinking Techniques. Two techniques that will be the focus in this lab are (1) brainstorming and (2) developing and keeping a project portfolio.

Brainstorming is typically thought of as generating as many ideas as possible in a predetermined amount of time. Because criticism and negative attitudes inhibit creativity during the concept generation phase, one should have established rules within the group that prevent anyone from criticizing the ideas.

Though not all sources completely agree on how to become more creative, a notebook of some type is always involved in the process. The notebook should contains sketches and notes from ideas and concepts that one encounters; it should not be limited to only subjects about one’s profession. The pages of the notebook should be dated and it is a good idea to leave a few pages in the beginning to add a table of contents. For the AEV project, a **project portfolio** will be used to track the teams’ progress, note taking and submitted work throughout the semester. The project portfolio will be done electronically that way the entire team has access to update the progress the team makes on the design project.

Lab Activity

For this lab each team member will need to print off orthographic drawing paper provided in Additional information on Creative Design Thinking techniques are also available in Appendix A – Creative Design Thinking Techniques as supplemental material for this lab.

This lab activity entails brainstorming ideas for an initial AEV design as a team.

1. *[Time Frame: 15-20 minutes]* The first task is for each group member to independently brainstorm on ideas of how the AEV should be designed/constructed. Each group member must complete a concept sketch in an orthographic view, see Figure 7. The components used in the AEV design should reflect the components provided in the AEV kit and/or components that can be used from outside of class. Before beginning to brainstorm be sure to review the list of design considerations listed below.

2. *[Time Frame: 15-20 minutes]* Now as a group, brainstorm ideas of how the AEV should be designed/constructed. Complete, as a group, a concept sketch in an orthographic view, see Figure 7. Remember, the components used on the AEV design should reflect the components provided in the AEV kit. Components from a hobby store or 3D printed can be used. Be sure to review the list of design considerations listed below.

3. As a team, begin working on construction of the initial AEV concept design. A fully constructed vehicle should be completed by Lab 03: Concept Screening and Scoring. *NOTE: Do NOT mount the motors and Arduino controller until after* Lab 02: Arduino Programming Basics*. These components will be needed for next week's lab.*

Design Considerations

1. Review the Mission Concept Review (MCR) for details of the operational requirements of the AEV.
2. ***NO METAL IS TO COME INTO CONTACT WITH THE AEV CONTROLLER BOARD.***
3. The AEV must traverse forward and backwards.
4. Energy usage should be minimized (weight, aerodynamics, etc.).
5. How many motors should be used and where should they be placed.
6. What propellers should be used provided in the AEV kit.
7. How can the vehicle be designed to handle variances in the track. (i.e., track independence – slight uphill, downhill variations may cause coasting)
8. *Bonus:* For all propellers there is a right and wrong way to orient the propeller. Rule of thumb is when looking at the propeller (i.e. AEV) from the front:
    a. *The propeller number designation should be visible.*

b. The propeller should be rotating ***counter-clockwise.***

Why is this important? Refer to Figure 7. Is the motor/propeller placement good for traversing *forward AND backward*?

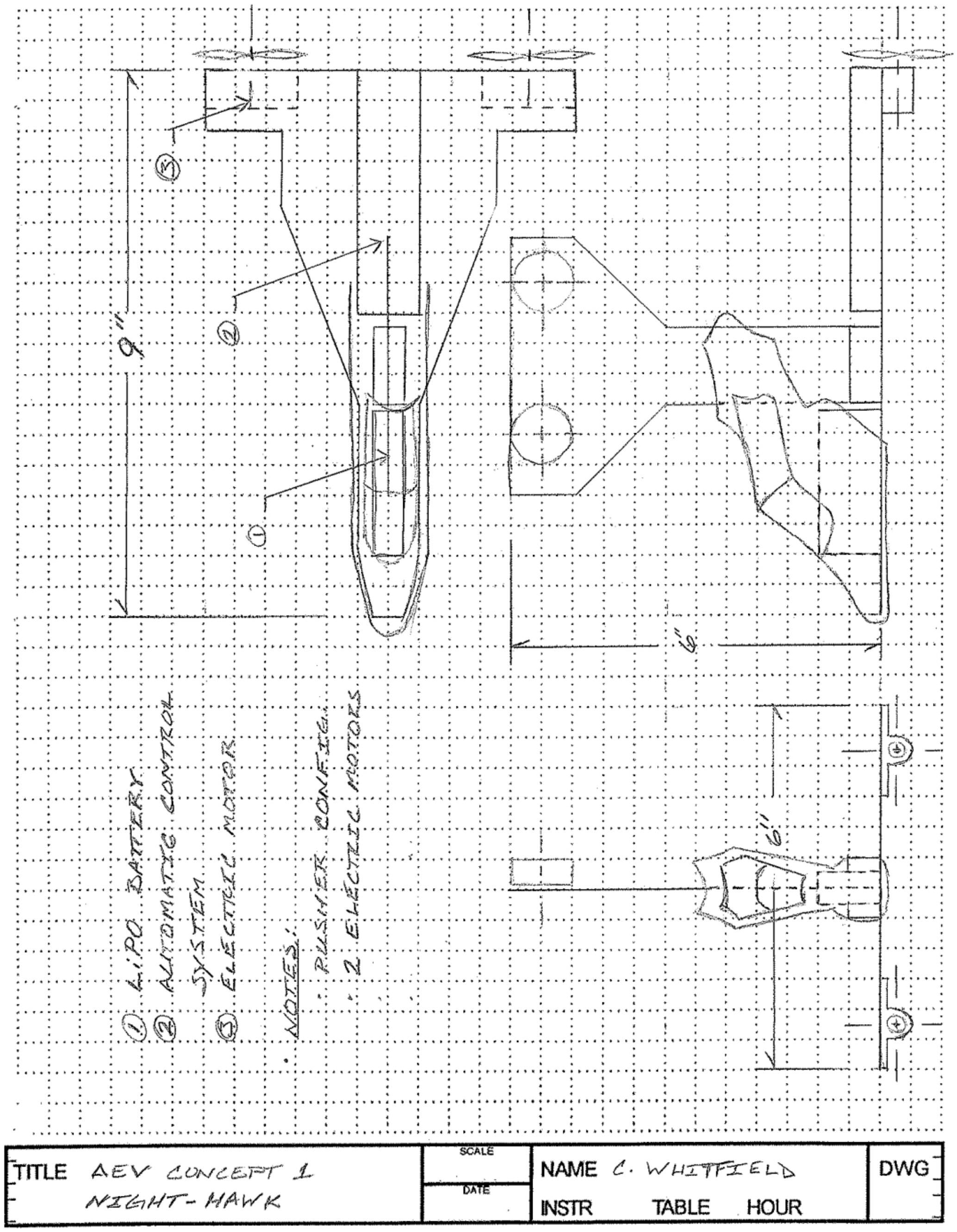


Figure 7: Example AEV Concept Sketch (Night-Hawk)

Executive Summary

(Due Lab 02: Arduino Basics)

Write an Executive Summary with formatting and content highlighted in the Technical Communications Guide under 'Executive Summary' for specifics. This summary is to be done as a team with the exception of the individual concept sketches (as seen in bullet point number three below).

In addition to the requirements listed in the Technical Communications Guides, be sure to briefly address the following questions. Answer within the summary and be sure not to use numbers or bullets.

- (QUESTION 1) Provide descriptions of the main features and motivations of each individual design. Describe how the designs differ for the team and how that change will improve or hinder the AEV's ability to complete the scenario (as stated in the Mission Concept Review (MCR)). Are there any specific design features that will aid in any component of completing the Mission Concept Review? Were there any specific techniques used for the brainstorming session of the lab?

- Provide each individual concept sketch. Each sketch needs to be hand-drawn in the 3 primary orthographic views with overall dimensions, scale, estimated weight, and an estimated Bill of Materials with the estimated cost of each part used (refer to the AEV kit checklist for AEV parts cost). Do not forget to fill out the title block. Orthographic paper is located in Appendix A – Creative Design Thinking Techniques).

- (QUESTION 2) Provide the descriptions of the main materials used in each individual design. Discuss how this will determine the characteristics of the final design. Will there be parts that will need to be fabricated or bought (3D printed, laser cut, and store bought materials)?

- Use the individual concept sketches and the discussion and create a team concept sketch (with 3 primary orthographic views with overall dimensions, scale, estimated weight, and an estimated Bill of Materials with the estimated cost of each part used) that will be used in Lab 03.

Grading Rubric – Lab 01: Creative Design Thinking

Instructor:____________________ GTA:____________________ Group:_____

Content

Executive Summary Content					Total
	Purpose		**Background**		
	5	Good / restated	5	Complete	
	3	Poor / copied	3	Incomplete / not specific	
	0	Lacking	0	Missing	__ 10
	Objectivity				
	3	Objective results			
	2	Some subjectivity			
	0	Mostly subjective			__ 3
	Question 1 – How Designs Differ		**Question 2 – Change Improve/Hinder**		
	3	Justified with data and theory	3	Justified with data and theory	
	2	Justified, incomplete data or theory	2	Justified, incomplete data or theory	
	1	Not fully reasoned / verified	1	Not fully reasoned / verified	
	0	Missing	0	Missing	__ 6
	Conclusions		**Team Concept Sketch**		
	5	Relevant & supported	6	Properly dimensioned, title box filled out, bill of materials, and cost	
	3	Unsupported / irrelevant	4	Lacking few components	
	2	Very lacking	1	Missing majority of components/poor	
	0	Missing	0	Missing all components	__ 11

Content Total / 30

Format & Language

Total

Content	Content	
	4 Appropriate content	
	2 Excess content / vague details	
	0 Vast excess content / content very vague	__ 4

Labels & References	Labels	Referencing	
	3 All present with good label descriptions	3 Well referenced & described in body	
	2 Some missing or poor descriptions	2 Poor descriptions and/or references	
	0 Missing or no description	0 Missing references	__ 6

General Format	Errors	
	4 Fewer than 2 mistakes	
	2 2-5 mistakes	
	0 More than 5 mistakes	__ 4

Structure	Brevity	Clarity	Flow	
	4 Concise	3 Clear	4 Smooth	
	2 Some wordy areas	2 Few parts confusing	2 Few disjointed parts	
	1 Very wordy	1 Many parts confusing	1 Many disjointed parts	
	0 Exceedingly poor	0 Confusing overall	0 Very disjointed	__ 11

Wording	Professionalism	Tense / Person	
	3 No slang, jargon, etc.	3 No slips in tense/person	
	2 Some slips in professionalism	2 1-3 slips in tense/person	
	1 Distracting / poor	1 4-8 slips in tense/person	
	0 Exceedingly poor	0 More than 8 errors	__ 6

General	Spelling / Grammar / Punctuation	
	4 Minor errors	
	3 Few errors, but not distracting	
	1 Distracts from readability	
	0 Complete lack of proofreading	__ 4

Writing Total / 35

Content Total / 30

Individual Content

A	Sketch		Title Box		Bill of Materials		
	7	Dimensioned, Top/Right/Front View, and orthographically aligned	4	Name, scale, title, date, instructor's name, team letter	4	Parts with bubbled locations on sketch, cost and weight of each part	
Appendix (Concept Sketch)	5	Lacking few dimensions, not aligned	3	Lacking one of the title box labels	3	Missing one of the above features	___ 15
	3	Poor / missing a view(s)	2	Lacking 2+ title box labels	2	Poor / Lacking Hard to follow	A
	0	Exceedingly poor / missing	0	Very poor / missing	0	Missing	

Student Name: ____ **Total** **/80**

Individual Content

B	Sketch		Title Box		Bill of Materials		
Appendix (Concept Sketch)	7	Dimensioned, Top/Right/Front View, and orthographically aligned	4	Name, scale, title, date, instructor's name, team letter	4	Parts with bubbled locations on sketch, cost and weight of each part	
	5	Lacking few dimensions, not aligned	3	Lacking one of the title box labels	3	Missing one of the above features	___ / 15
	3	Poor / missing a view(s)	2	Lacking 2+ title box labels	2	Poor / Lacking Hard to follow	B
	0	Exceedingly poor / missing	0	Very poor / missing	0	Missing	

Student Name: ____ **Total /80**

Individual Content

C		Sketch		Title Box		Bill of Materials
Appendix (Concept Sketch)	7	Dimensioned, Top/Right/Front View, and orthographically aligned	4	Name, scale, title, date, instructor's name, team letter	4	Parts with bubbled locations on sketch, cost and weight of each part
	5	Lacking few dimensions, not aligned	3	Lacking one of the title box labels	3	Missing one of the above features
	3	Poor / missing a view(s)	2	Lacking 2+ title box labels	2	Poor / Lacking Hard to follow
	0	Exceedingly poor / missing	0	Very poor / missing	0	Missing

____ 15

C

Student Name: ____ **Total /80**

Individual Content

D	Sketch		Title Box		Bill of Materials	
Appendix (Concept Sketch)	7	Dimensioned, Top/Right/Front View, and orthographically aligned	4	Name, scale, title, date, instructor's name, team letter	4	Parts with bubbled locations on sketch, cost and weight of each part
	5	Lacking few dimensions, not aligned	3	Lacking one of the title box labels	3	Missing one of the above features
	3	Poor / missing a view(s)	2	Lacking 2+ title box labels	2	Poor / Lacking Hard to follow
	0	Exceedingly poor / missing	0	Very poor / missing	0	Missing

___ / 15

D

Student Name: ____ Total /80

Lab 02: Arduino Programming Basics

Objectives

1. Become familiar with the automatic control system hardware components.
2. Setup the AEV software.
3. Program the basic function calls in controlling the AEV.
4. Be able to upload programs on the Arduino and test.
5. Become familiar with troubleshooting techniques.

Lab Equipment

1. AEV motor mount desktop stand (Provided in Lab. See Figure 8).
2. AEV Controller (Provided in AEV kit).
3. Two Motors (Provided in AEV kit).
4. USB Cable (Provided in AEV kit).
5. Li-Po Battery (Provided in Lab. Must check out with Buck-ID).

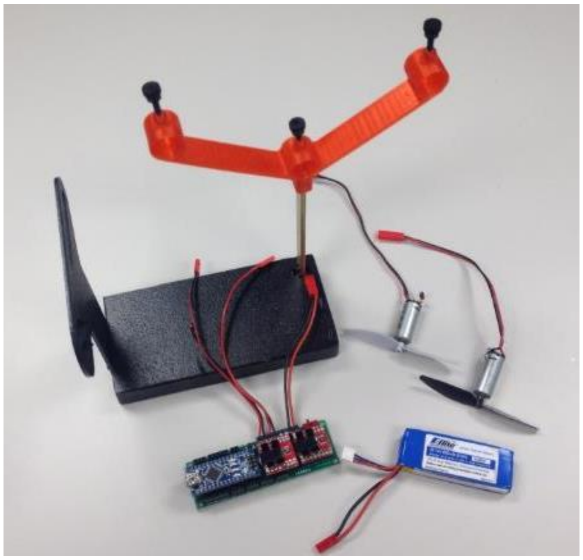


Figure 8: Motor stand with Lab 02 required equipment

Background: The AEV Controller

The AEV Controller is a custom-made automatic controller and performance recorder system featuring an off-the-shelf Arduino Nano microcontroller and two motor chips, see Figure 9. This system was designed to be light weight (~43 grams), small for product design (1.2" x 3.7" x 0.625"), and to make use of a simple microcontroller with easy to use software. For more details on the motherboard layout and external parts and assembly see Appendix B – AEV Controller.

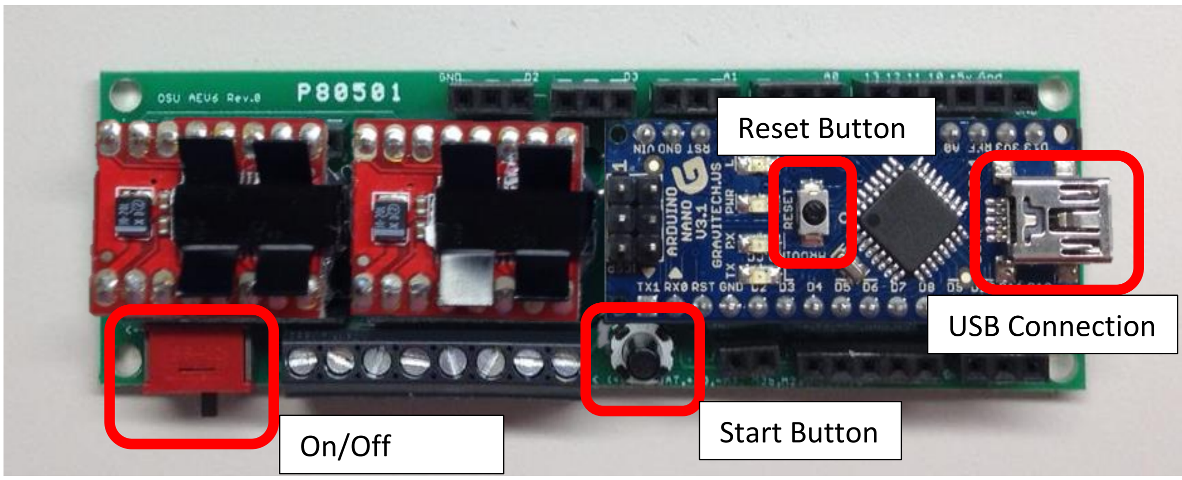


Figure 9: The AEV controller with an Arduino Nano

The Arduino Nano is considered the heart of the AEV controller and will be used to control motor speeds, the time or distance the motors run for, and recording system data (introduced later in Lab 05: System Analysis 1). The Arduino Nano microcontroller uses the open source Arduino Integrated Development Editor (IDE). The software is available for free at http://www.arduino.cc.

The Arduino programming language is very similar to C or C++ syntax. There is no prior programming experience in C or C++ is required for this project. A team of engineers has already developed the background software required for operating the motors of the AEV and have made it so operating the AEV is done using "function calls" in the software. Calling on these functions is very similar in syntax as it is done in MATLAB.

A description of the function calls are provided below. Note that more function calls will be introduced in later labs.

Basic Function Calls

- **celerate(m,p1,p2,dt);**
  - Accelerates or decelerates motor(s) **m** from start speed (%) **p1** to end speed (%) **p2** over the duration of **dt** seconds.
  - Four Arguments
    - m: Motor number 1, 2, or 4 for all motors.
    - p1: Start % speed (0% – 100%)
    - p2: End % speed (0% – 100%)
    - dt: Time span for celeration in seconds (1 – 10)
  - Example: **celerate(4,20,45,2);**
    - Will accelerate all motors from 20% to 45% full power in 2 seconds.
  - Example: **celerate(2,40,0,4);**
    - Will decelerate motor 2 from 40% to 0% full power in 4 seconds.

- **motorSpeed(m,p);**
  - Initializes motor(s) **m** at percent power **p**.
  - Two Arguments
    - m: Motor number 1, 2, or 4 for all motors.
    - p: % Speed (0 – 100)
  - Example: **motorSpeed(2,16);**
    - Sets motor 2 speed to 16% full power

- **goFor(dt);**
  - Runs the motor(s) at their initialized state for **dt** seconds.
  - One Argument
    - dt: Time span in Seconds
  - Example: **goFor(5);**
    - Runs the motor(s) at their initialized state for 5 seconds

- **brake(m);**
  - Brakes motor(s) **m**. NOTE: This does not brake the AEV.
  - One Argument
    - m: Motor number 1, 2, or 4 for all motors.
  - Example: **brake(2);**
    - Cuts the power from motor 2.

- **reverse(m);**
  - Reverses the polarity of motor(s) **m**.
  - One Argument
    - m: Motor number 1, 2, or 4 for all motors.
  - Example: **reverse(2);**
    - Reverse motor 2

Lab Activity

Equipment Setup

1. ***Before mounting the propellers on the motors***, it is important to note that propellers provide more thrust when mounted with the dull side of the propeller (the side with writing) facing the direction the vehicle is traveling. For this lab, mount the propellers with the dull side facing away from the motor casing.
2. ***To mount the propeller on the motors***, place the propeller hub flat on the table. Now place the motor over the propeller and push the motor spindle into the propeller. Refer to Figure 10 for a visual representation.

Figure 10: Properly installing a propeller to the motor

3. The propeller should have a tight fit onto the motor spindle. **If a propeller feels like it will slide off easily notify an instructional team member for a replacement.**
4. Place the AEV controller and motors in motor stands as displayed in Figure 8.
5. ***AEV electrical connections best practice: Motors first, battery last!***
    a. Never plug a battery directly into a motor. This may cause damage to the battery and the motor and ruin the lab for the whole group. Don't be that guy (or gal). If unsure at first, always feel free to ask an instructional team member for help.
6. Connect motors 1 & 2. Note: The motor connections on the Arduino will have male connections.
7. Make sure the power switch on the Arduino is in the OFF position. Orient the Arduino controller such that the red On/Off switch is on the left hand side facing towards the user. The switch should be all the way to the right in the OFF position.
8. Connect the battery. Note: The battery connection on the Arduino will have a female connection

9. AGAIN, DO **NOT** EVER PLUG THE MOTOR WIRE INTO THE BATTERY WIRE.

The setup should look similar to Figure 11.

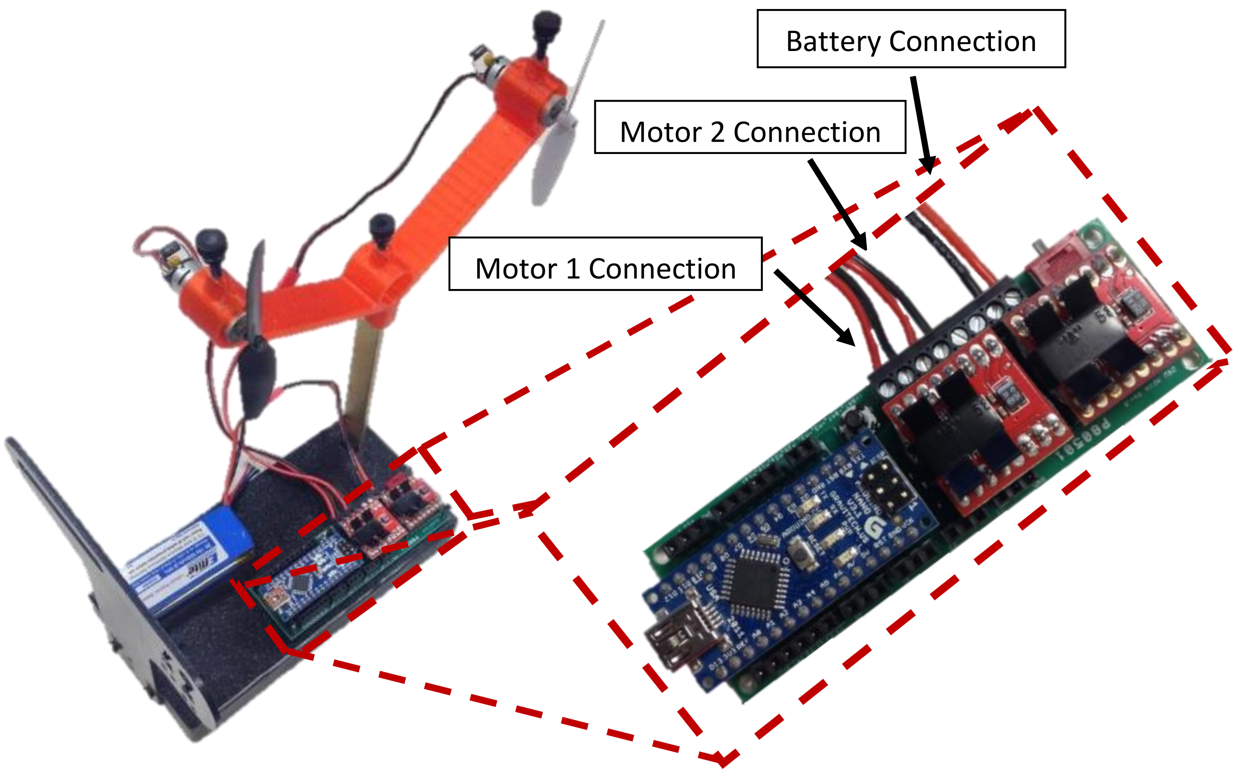


Figure 11: Lab and AEV parts assembled

AEV Sketchbook Download

Now that the experimental setup is complete, the next step is to learn about the Arduino software.

1. Go to the EEIC courses website and select the link "**AEV Documents**" under the Lab 02 web page.
2. The AEV software is contained within a zip folder called "Sketchbook". Download the **Sketchbook** zip-folder by selecting the link and save the zip folder to a flash drive or the Z: drive on the lab computer.
3. Unzip the folder by right-clicking on the zipped folder -> 7-Zip -> Extract Here.

The Arduino IDE

The Arduino IDE is an open source programming environment that will be used for programming the AEV controller.

1. Open the Arduino IDE from Start → All Programs →Arduino

Arduino Sketchbook Setup

In the Arduino IDE, the folder (i.e., sketchbook) location on the computer must be set in the program. Another way to think of this is an example of working in MATLAB. In order to run a script file in MATLAB the working directory in MATLAB must first be set to the location of the MATLAB script/function while being used. In this lab this is referred to as "sketchbook setup".

To setup the AEV sketchbook, follow these steps:

1. Under the File menu select Preferences.
2. A separate window will appear. See Figure 12.
3. Under "Sketchbook location" (at the top of the window) select "Browse" and select the sketchbook folder, then click ok. Note: Do not click into the sketchbook folder. Only select the folder (by making sure the folder is highlighted).

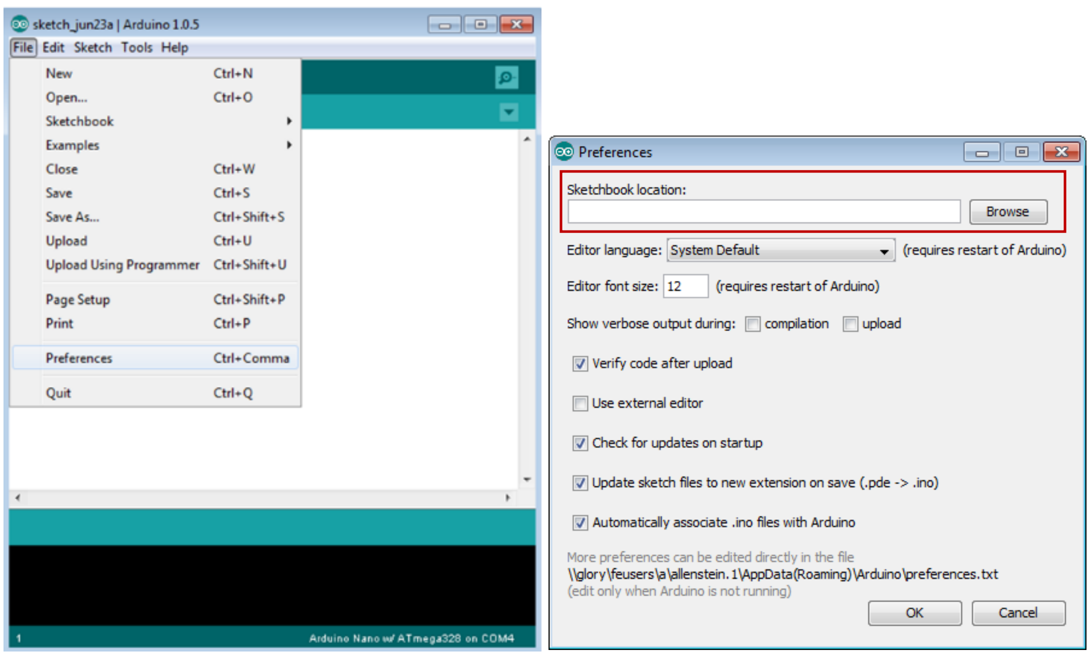


Figure 12: Setting the Arduino Sketchbook Location

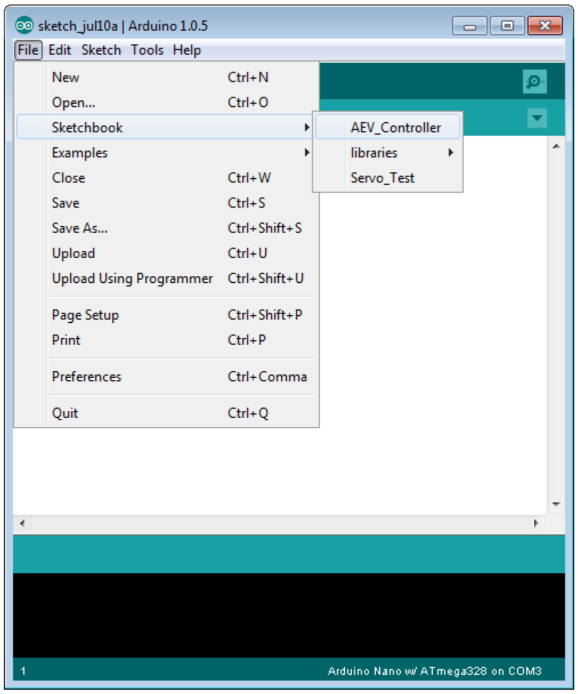


Figure 13: AEV Sketchbook Files in Arduino IDE

4. Now select File, then sketchbook. The files that are in the sketchbook folder as shown in Figure 13.
5. Now close out of Arduino completely and restart the program. This step is necessary because now that the sketchbook location has been changed Arduino needs to "reset" itself to take into account the change made. If this step is not completed Arduino will give out a "Metro" error when the program is being uploaded to the AEV controller.

AEV_Controller Layout

Now that the sketchbook location has been set, the main program can be open.

- Select AEV_Controller under File → Sketchbook.

A second Arduino window will open similar to Figure 14. The previous blank Arduino window can be closed.

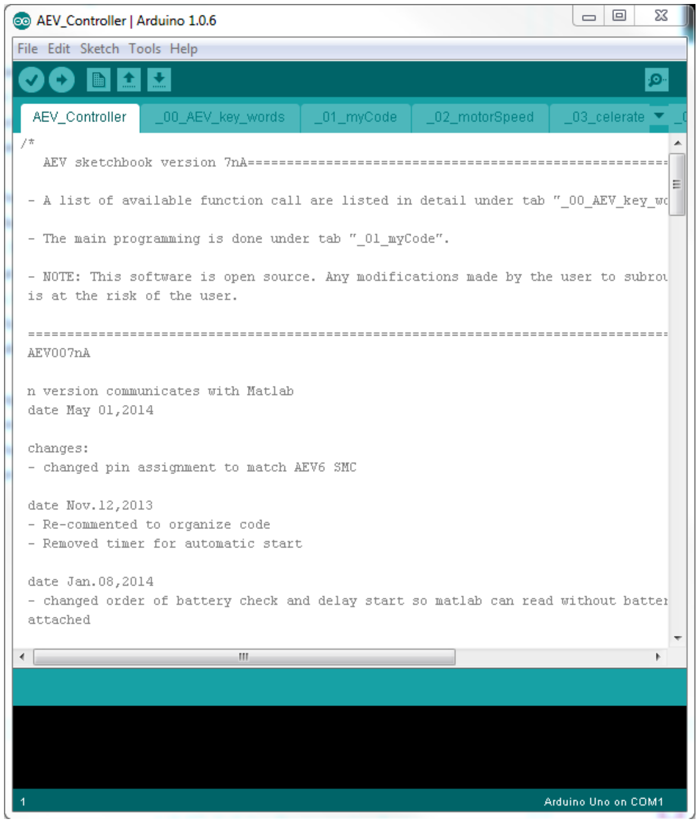


Figure 14: AEV_Controller Screen Shot.

The AEV_Controller program is the part of the software that has already been developed for the AEV project. In the Arduino window there will be tabs at the top of the window. The main tab (left most tab) has the tab label "AEV_Controller". This is the main tab of the AEV_Controller program. All other tabs are separate functions used in the main program.

The tab that will be used to input commands for operating the AEV is the "01_myCode" tab. Select this tab. A sample program is already included. This is where programming the functions for controlling the AEV occurs.

Programming Basics Exercise

As a teams, program Scenario 1 using the basic Arduino function calls. NOTE: For each line of code, *write comments describing what the line of code is doing*. For example:

```
// Reverse motor one
reverse(1);
```

OR

```
reverse(1);  // Reverse motor one
```

Scenario 1:

1. Accelerate motor one from start to 15% power in 2.5 seconds.
2. Run motor one at a constant speed (15% power) for 1 second.
3. Brake motor one.
4. Accelerate motor two from start to 27% power in 4 seconds.
5. Run motor two at a constant speed (27% power) for 2.7 seconds.
6. Decelerate motor two to 15% power in 1 second.
7. Brake motor two.
8. Reverse the direction of only motor 2.
9. Accelerate all motors from start to 31% power in 2 seconds.
10. Run all motors at a constant speed of 35% power for 1 second.
11. Brake motor two but keep motor one running at a constant speed (35% power) for 3 seconds.
12. Brake all motors for 1 second.
13. Reverse the direction of motor one.
14. Accelerate motor one from start to 19% power over 2 seconds.
15. Run motor two at 35% power while **simultaneously** running motor one at 19% power for 2 seconds.
16. Run both motors at a constant speed (19% power) for 2 seconds.
17. Decelerate both motors to 0% power in 3 seconds.
18. Brake all motors.
19. Save Program as (Save As:) PrgmBasics

Uploading Arduino Programs

1. Once the program has been saved it can be found under File → sketchbook, the name of the saved program.
2. Connect the AEV board to the computer using the USB cable provided. Make sure the power switch is in the OFF position.
3. Now the proper Board, Processor, and Serial Port must be set in the Arduino IDE.
   a. To set the board, go to: Tools → Board, then select Arduino Nano.
   b. To set the processor, go to: Tools → Processor, then select ATmega328

c. To set the serial port, go to: Tools → serial port, and select the <u>last</u> COM port available in the list (usually COM3 or if there is a flash drive plugged in COM4).

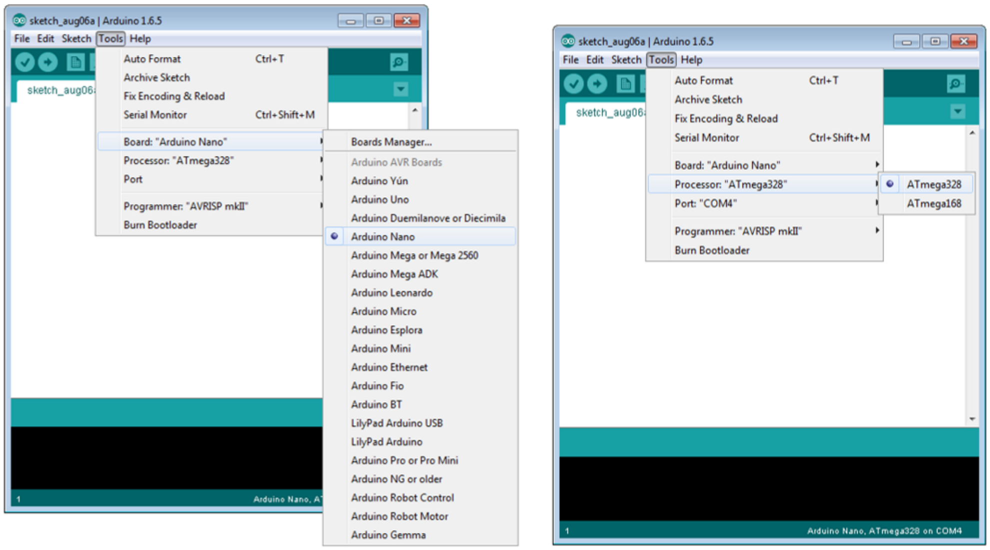


Figure 15: Setting the Arduino Board and Serial Port

4. Compile the program to check for syntax errors by selecting the compile button. Then upload the program to the Arduino by selecting the upload button on the tool bar. See trouble shooting section at the end of this section if there are difficulties with this step.

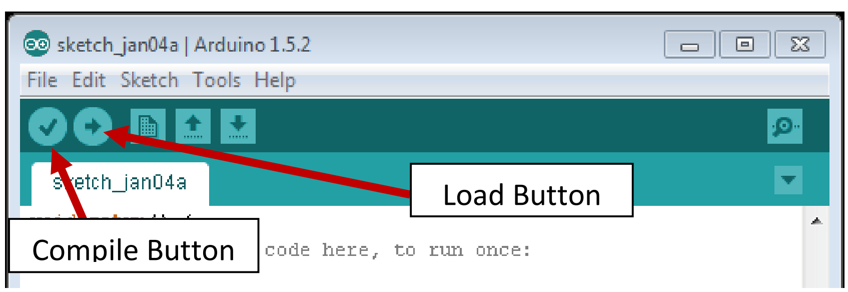


Figure 16: Arduino Compile and Load Button

5. The Arduino software informs you that it is uploading and when it is complete.
   - While uploading, observe the lights flashing on the Arduino. If they are flashing fast, that is an indication that the proper board and com port have been set.
6. Unplug the USB cable from the Arduino after the program is uploaded.
7. Turn on power switch.
8. Wait until yellow light on the Arduino turns solid.
9. *Make sure that your team knows that the AEV is about to run the program.*
10. Make sure nothing is in the propeller plane! It's not common, but propellers can fly off.

11. Push the start button that is near the Arduino board of the automatic control system. There will be a yellow/white light on the Arduino board that will flash 4 times before starting.
12. Once the program is finished, wait approximately 10 seconds, and then turn off the power switch.
    - The waiting portion is to allow the Arduino to process data. Even though downloading the data will not occur until Lab 05: System Analysis 1, it is good practice to start this waiting process.
13. If time permits, try Scenario 2, the "fun" code (Hint: think of Star Wars).

Scenario 2 (Fun):

1. Reverse all motors.
2. Power all motors at 25% power for 0.5 second.
3. Brake all motors for 0.1 seconds.
4. Repeat steps 2 and 3 at total of 2 times
5. Power all motors at 15% power for 0.3 second.
6. Brake all motors for 0.05 seconds.
7. Power all motors at 40% power for 0.3 second.
8. Power all motors at 25% power for 0.5 second.
9. Power all motors at 15% power for 0.3 second.
10. Brake all motors for 0.05 seconds.
11. Power all motors at 40% power for 0.3 second.
12. Power all motors at 25% power for 0.5 second.
13. Brake all motors for 0.5 seconds.
14. Power all motors at 55% power for 0.5 second.
15. Brake all motors for 0.1 seconds.
16. Repeat steps 14 and 15 a total of 2 times
17. Power all motors at 65% power for a total of 0.3 second.
18. Brake all motors for 0.05 seconds.
19. Power all motors at 40% power for 0.3 second.
20. Power all motors at 20% power for 0.5 second.
21. Power all motors at 15% power for 0.3 second.
22. Brake all motors for 0.05 seconds.
23. Power all motors at 40% power for 0.3 second.
24. Power all motors at 25% power for 0.5 second.
25. Brake all motors.
26. Save Program as (Save As:) PrgmBasicsStarWars

Executive Summary

(Due Lab 03: Concept Screening and Scoring)

Write an Executive Summary with formatting and content highlighted in the Technical Communications Guide under 'Executive Summary' for specifics.

In addition to the requirements listed in the Technical Communications Guides, be sure to briefly address the following questions. Answer within the summary and be sure not to use numbers or bullets.

- (QUESTION 1) Comment on the performance of the electric motors. (i.e., in scenario 1 line 1, did the propeller begin to rotate at the start of the program or was there resistance observed in the motor to rotate the propeller at low speeds?).

- (QUESTION 2) Discuss how the commands used in this lab may limit the success of the AEV in its completion of the scenario Hint: by applying the "brake(m);" command, will an AEV stop right away?

- (RESOLVING ERROR) Discuss any potential errors made and how these were resolved during the lab. Was the team able to complete both scenarios? What was scenario 2?

- (RECOMMENDATIONS) Refer to QUESTION 2 above. Did the team need more guidance on any of lab material or are there recommendations to make the lab a better experience.

Lastly, provide a copy (or copies) of the Arduino Programming Basics Arduino Code using the format laid out in the Technical Communications Guide.

Grading Guidelines – Lab 02: Arduino Programming Basics

Instructor:____________________ GTA:____________________ Group:_____

Content

Executive Summary Content					Total
	Purpose		Background		
	3	Good / restated	3	Complete	
	1	Poor / copied	1	Incomplete / not specific	
	0	Lacking	0	Missing	__ 6
	Objectivity		Analysis		
	4	Objective results	5	Clear trends identified	
	2	Some subjectivity	3	Trends unrelated	
	0	Mostly subjective	0	Not reasoned / verified	__ 9
	Question 1: Discussion of Energy/Motors		Question 2: Discussion of Commands		
	6	Justified with observations	6	Justified with theory	
	3	Justified, incomplete observations	3	Justified, incomplete theory	
	2	Not fully reasoned / verified	2	Not fully reasoned / verified	
	0	Missing	0	Missing	__ 12
	Resolving Error		Recommendations		
	5	Addresses error / reasonable	5	Reasonable & 2 or more	
	3	Unaddressed or unreasonable	3	Somewhat lacking	
	2	Lacking thought	2	Not fully reasoned	
	0	Missing	0	Missing	__ 10
	Conclusions		Copy of Arduino Code		
	5	Relevant & supported	3	Attached / Commented / Correct	
	3	Unsupported / irrelevant	2	Attached / Missing Section(s)	
	2	Very lacking	1	Very Lacking	
	0	Missing	0	Missing	__ 8

Content Total / 45

Format & Language

Total

Content	Content		Total
	4	Appropriate content	
	2	Excess content / vague details	
	0	Vast excess content / content very vague	__ 4

Labels & References	Labels		Referencing		Total
	3	All present with good label descriptions	3	Well referenced & described in body	
	2	Some missing or poor descriptions	2	Poor descriptions and/or references	
	0	Missing or no description	0	Missing references	__ 6

General Format	Errors		Total
	4	Fewer than 2 mistakes	
	2	2-5 mistakes	
	0	More than 5 mistakes	__ 4

Structure	Brevity		Clarity		Flow		Total
	4	Concise	3	Clear	4	Smooth	
	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts	
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts	
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed	__ 11

Wording	Professionalism		Tense / Person		Total
	3	No slang, jargon, etc.	3	No slips in tense/person	
	2	Some slips in professionalism	2	1-3 slips in tense/person	
	1	Distracting / poor	1	4-8 slips in tense/person	
	0	Exceedingly poor	0	More than 8 errors	__ 6

General	Spelling / Grammar / Punctuation		Total
	4	Minor errors	
	3	Few errors, but not distracting	
	1	Distracts from readability	
	0	Complete lack of proofreading	__ 4

Writing Total / 35

Content Total / 45

Total / 80

Instructor/ GTA End-of-Lab Signoff

Lab 2: ____

Lab 03: Concept Screening and Scoring

Objectives

1. Become familiar with techniques for design decision making.
2. Become familiar with a structured method to screen and score design concepts.
3. Program the sample AEV for a specific operation and test on classroom track.
4. Perform concept screening and scoring methods with AEV design concepts using the sample AEV as the reference.

Lab Equipment

1. Constructed initial AEV (do **not** attached the external sensors)
2. USB Cable
3. Li-PO Battery
4. Desktop Stand

Background: Concept Screening and Scoring Matrices

The team is required to determine the success criteria that fits the AEV design, and screen and score the design concepts. The reference AEV should be the one the instructor ran as a demo. The AEV the instructor ran is the reference. Notice how the sample is a stable system but not a very creative, energy efficient system? There are different types of decision methods that can help lead to a final product. Some of the decision methods include (but not limited to): external decision, product champion, intuition, multi-voting, pros and cons, prototype and test, and decision matrices. Lab 03 utilizes decision matrices which uses selection criteria to weigh against prioritized requirements. These concept screening and scoring matrices are decision matrices that will be used.

A concept screening matrix is a quick method to down-select ides. It is used to combine various concepts or parts and is sometimes good enough for simple projects. To perform the concept screening, the team needs to come up with criteria to compare to the reference AEV against the designs created in Lab 01: Creative Design Thinking and any other designs the team may have come up with. A zero means that the design is equal or neutral in comparison to the reference AEV. A positive sign means the design is better than the reference AEV and a minus sign is that the design is worse compared to the reference. From there, add all symbols to determine which design would complete the scenario in the Mission Concept Review (MCR). Table 2 is an example of a concept screening matrix.

Table 2: Example Concept Screening Scoresheet

Success Criteria	Reference	Design A	Design B	Design C	Design D	Design E	Design F
Balanced Around Turns	0	0	0	-	0	-	-
Minimal blockage	0	0	-	-	0	+	0
Center-of-gravity location	0	0	0	+	+	0	+
Maintenance	0	0	0	0	-	0	0
Durability	0	0	0	0	0	+	0
Cost	0	+	-	-	0	-	0
Environmental	0	+	+	0	+	0	0
Sum +'s Sum 0's Sum –'s	0 7 0	2 5 0	1 4 2	1 3 3	2 4 1	2 3 2	1 5 1
Net Score	0	2	-1	-2	1	0	0
Continue?	Combine	Yes	No	No	Yes	Combine	Revise

A concept scoring matrix provides a better resolution than a screening matrix. Concept scoring matrices may provide better definition of concepts and help define the final project. This type of decision method may play a deciding role later in the semester (when revisited in the Preliminary Design Review (PDR) Report and the Performance Tests). This method creates or refines a hierarchy of "selection criteria" on which success criteria plays a dominate role in the final design.

To perform a concept scoring matrix, take the success criteria from the concept screening matrix and give each criteria a weight (of importance) percentage adding up to 100 percent. Take each design and give each one a rating (on a scale of 0-5 points) of the success criteria (can use the reference AEV as the reference. The weighted score is calculated by taking the rating multiplied by the weight (as a decimal). From there, add all symbols to determine which design would complete the scenario in the Mission Concept Review (MCR). Table 3 is an example of a concept scoring matrix. This is a design process is an iterative process that will continue the duration of the project until the final AEV design has been created.

Table 3: Sample Concept Scoring Matrix

Success Criteria	Weight	A Reference		Design X		Design Y		Design Z	
		Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score	Rating	Weighted Score
Balanced	5%	3	0.15	3	0.15	4	0.20	4	0.20
Minimal blockage	15%	3	0.45	4	0.60	4	0.60	3	0.45
Center-of-gravity location	10%	2	0.20	3	0.30	5	0.50	5	0.50
Maintenance	25%	3	0.75	3	0.75	2	0.50	3	0.75
Durability	15%	2	0.30	5	0.75	4	0.60	3	0.45
Cost	20%	3	0.60	3	0.60	2	0.40	2	0.40
Environmental	10%	3	0.30	3	0.30	3	0.30	3	0.30
Total Score			2.75		3.45		3.10		3.05
Continue?		No		Develop		No		No	

Lab Activity

1. **As a team:**
   If it is not already assembled, build an AEV from the team's design concepts from Lab 01: Creative Design Thinking. **Do *NOT* mount the wheel count sensors.**
2. Program the assembled AEV for the following scenario on the straight tracks located in the front and back of the classroom:

STRAIGHT TRACK

1. Accelerate all motors from start to 25% in 3 seconds.
2. Run all motors at a constant speed (25% power) for 1 second.
3. Run all motors at 20% power for 2 seconds.
4. Reverse all motors.
5. Run all motors at a constant speed (25% power) for 2 second.
6. Brake all motors.
7. Save the program as CSS1.

3. Once the program has been constructed, demonstrate the team's program works ***statically*** (using the desktop stands) to an instructional team member.
   Get verification from the instructional team member to test on the classroom track.

4. Test the AEV on the track following the **proper testing procedures** (see Testing Procedure). Only one AEV design needs to complete the run.

5. Develop success criteria that would be beneficial in evaluating the team's designs.

6. Perform concept screening for each of the design concepts created in Lab 01: Creative Design Thinking. Again, only one AEV needs to be constructed and ran. Use the instructor's AEV as a baseline

Executive Summary

(Due Lab 04: External Sensors)

Write an Executive Summary with formatting and content highlighted in the Technical Communications Guide under 'Executive Summary' for specifics.

In addition to the requirements listed in the Technical Communications Guides, be sure to briefly address the following questions. Answer within the summary and be sure not to use numbers or bullets.

- (QUESTION 1) Describe how the AEV ran on the test track with the scenario code (Things to keep in consideration; how was the balance of the AEV, was it leaning to one side, did the AEV move right away when the code was activated, etc.)

- Provide a completed copy of the Concept Screening **and** Scoring Spreadsheets (with descriptions of the criteria choices and what the spreadsheets are representing).

- (QUESTION 2) Discuss the pros and cons of each design as compared to the Reference AEV using the concept screening and scoring spreadsheets to help for justification. Use these matrices to define which AEV concept will be carried forward in the design cycle.

Lastly, provide a copy of the Concept Screening and Scoring Arduino Program using the format laid out in the Technical Communications Guide.

Grading Guidelines – Lab 03 Concept Screening and Scoring

Instructor:____________________ GTA:____________________ Group:_____

Content

Executive Summary Content

Purpose		Background		Total
3	Good / restated	3	Complete	
1	Poor / copied	1	Incomplete / not specific	__
0	Lacking	0	Missing	6
Objectivity		**Analysis**		
4	Objective results	5	Clear trends identified	
2	Some subjectivity	3	Trends unrelated	__
0	Mostly subjective	0	Not reasoned / verified	9
Question 1: AEV Behavior		**Question 2: Pro(s)/Con(s) of each Design**		
3	Justified with data and observations	3	Justified with data and theory	
2	Justified, incomplete data or observations	2	Justified, incomplete data or theory	
1	Not fully reasoned / verified	1	Not fully reasoned / verified	___
0	Missing	0	Missing	6
Resolving Error		**Recommendations**		
5	Addresses error / reasonable	3	Reasonable & 2 or more	
3	Unaddressed or unreasonable	2	Somewhat lacking	
2	Lacking thought	1	Not fully reasoned	___
0	Missing	0	Missing	8
Conclusions		**Copy of Arduino Code**		
5	Relevant & supported	3	Attached / Commented / Correct	
3	Unsupported / irrelevant	2	Attached / Missing Section(s)	
2	Very lacking	1	Very Lacking	___
0	Missing	0	Missing	8
Concept Screening Matrix		**Concept Scoring Matrix**		
4	Justified / 5 scoring criteria	4	Justified / 5 scoring criteria	
2	Lacking criteria or explanation	2	Lacking criteria or explanation	
1	Not reasoned	1	Not reasoned	___
0	Missing	0	Missing	8

Content Total / 45

Total

Format & Language

Content	Content		
	4	Appropriate content	
	2	Excess content / vague details	
	0	Vast excess content / content very vague	___ / 4

Labels & References	Labels		Referencing		
	3	All present with good label descriptions	3	Well referenced & described in body	
	2	Some missing or poor descriptions	2	Poor descriptions and/or references	
	0	Missing or no description	0	Missing references	___ / 6

General Format	Errors		
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	2	2-5 mistakes	
	0	More than 5 mistakes	___ / 4

Structure	Brevity		Clarity		Flow		
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	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts	
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts	
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed	___ / 11

Wording	Professionalism		Tense / Person		
	3	No slang, jargon, etc.	3	No slips in tense/person	
	2	Some slips in professionalism	2	1-3 slips in tense/person	
	1	Distracting / poor	1	4-8 slips in tense/person	
	0	Exceedingly poor	0	More than 8 errors	___ / 6

General	Spelling / Grammar / Punctuation		
	4	Minor errors	
	3	Few errors, but not distracting	
	1	Distracts from readability	
	0	Complete lack of proofreading	___ / 4

Writing Total	/ 35
Content Total	/ 45
Total	/ 80

Instructor/ GTA End-of-Lab Signoff

Lab 3: ______________________________________

Lab 04: External Sensors

Objectives

1. Become familiar with the external sensor hardware components.
2. Become familiar with troubleshooting techniques.
3. Program function calls for using external sensors with AEV control.

Lab Equipment

1. Constructed AEV
2. External Sensors
3. Zip ties (will be provided by the instructor)
4. USB Cable
5. Li-PO Battery
6. Desktop Stand

Background: External Sensors

The last piece of equipment to introduce are the reflectance sensors. The Reflectance Sensors have a single infrared LED and a small phototransistor on the red board. This sensor works in hand with the wheel that has the reflective tape as illustrated in Figure 17.

Figure 17: Reflectance Sensor (LEFT) and wheel with reflective tape (RIGHT) (https://www.pololu.com/product/2458)

The phototransistor and a pull-up resistor are connected to form what is called a voltage divider. The voltage divider produces an analog voltage output that is a function of the inferred signal. If the voltage divide indicates a low output voltage, this is an indication of greater reflection (say from the aluminum tape). The Arduino will record each time a non-reflective surface passes over the sensor as a “mark” which can be converted into engineering units. This is indicative in Figure 18 where the large voltage change (maxima on the graph) will be recorded as 1 mark.

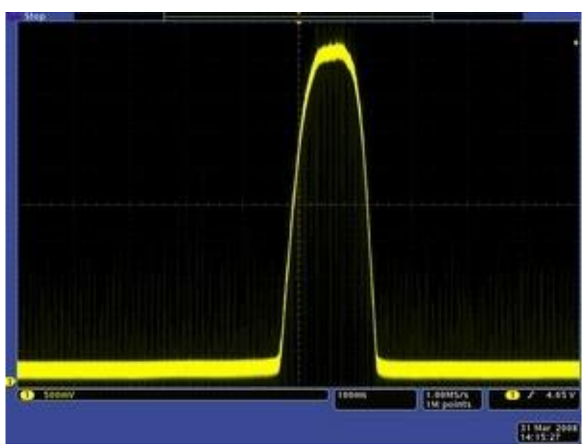

Figure 18: Reflective Sensor 1/8 inch away from a spinning white disk with a white line on it (https://www.pololu.com/product/2458)

It is very important to ensure that the sensor is as close to the wheel with the tape to ensure a good signal is acquired. If the sensor is too far away a mark may not be record. Such event occurred when the sensor was 3/8 inch away as shown in Figure 19. So verify that the sensor is as close to the wheel as possible to eliminate light pollution or missed mark recordings.

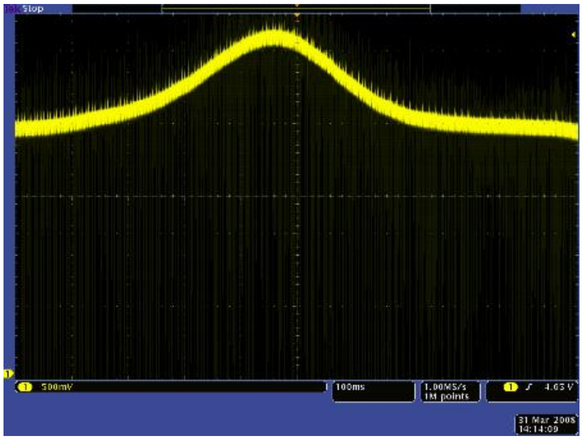

Figure 19: Reflective Sensor 3/8 inch away from a spinning white disk with a white line on it (https://www.pololu.com/product/2458)

Also provided in the kit is a Servomechanism or Servo for short. This device is used to provide control of an angular position. Some servos can provide control of velocity and acceleration. Typically servos are control by pulse width modulation (PWM) which is the sending of an electrical pulse of a variable width. The Tower Pro micro servo is a tiny servo (small compared to many standard servos) that has a range of rotation from approximately 0-180 degree (Servos do not reach exactly the full 0 to 180 degree by are close to these values).

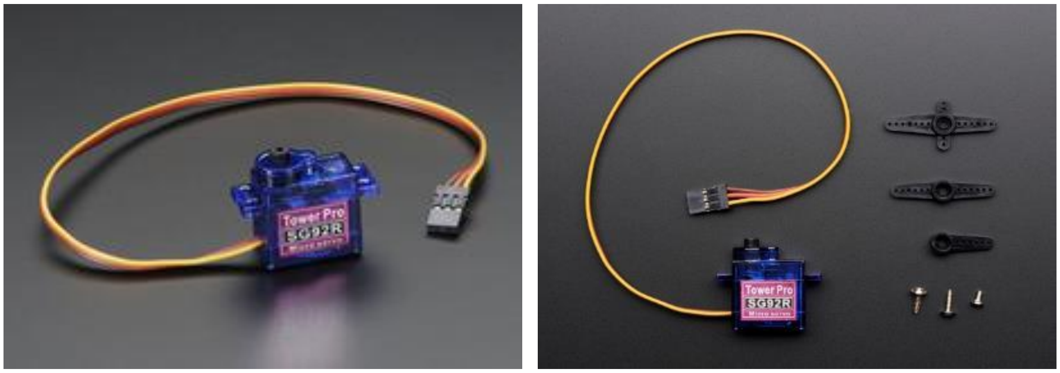

Figure 20: Tower Pro SG92R Micro Servo (http://www.adafruit.com/product/169)

Lab Activity

Installing Reflectance Sensors

The reflectance sensors are wired to connect directly to the automatic control system. Both of the vertical support arms provided in the kits have direct capability to mount the sensors on the opposite side of the wheel. Use the small #2 bolt, nut, and zip tie in the AEV kit to secure the two reflectance sensors to the vertical support as shown in Figure 21.

Attach sensors using #2 bolt & nut. Do not zip tie until instructed to zip tie.

Figure 21: Reflectance Sensor Connection to AEV Support Arm (Note: the black wire is in the GND port of the reflectance sensor)

The figure below shows the reflectance sensor ports on the automatic control system. The 3-prong plug must be oriented such that the white wire must be in the port closest to the mini-USB connection on the automatic control system.

Important Note: Make sure the connections are installed with the white wire facing the Arduino mini-USB connection.

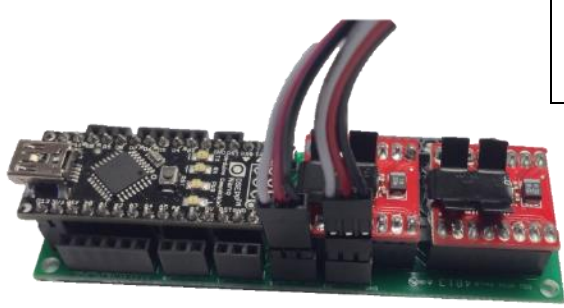

Figure 22: Reflectance Sensor Connection (note: the black wire is in the GND port of the green circuit board)

Verify that the small screws are flush against the support arm. If the screws stick out, this causes unnecessary drag and could tear the tape providing inaccurate results. If the screws are sticking out, call for an instructor to help the team countersink the screw holes.

It is always a good idea to verify, where possible, any new addition to a project. In this case, after mounting the sensors, test that they work properly. Conduct the following steps:

Testing the Reflectance Sensors

1. Open Arduino software: Start → All Programs.
2. Set sketchbook preferences if needed (see Lab 02: Arduino Programming Basics).
3. Type in “reflectanceSensorTest();” into 01_myCode
4. Connect the Arduino controller using the USB cord provided and upload the code to the Arduino. NOTE: Keep the Arduino controller connected to the computer throughout this test.
5. When the code is uploaded, open the serial monitor: Tools → Serial Monitor.
6. Set the monitor to 115200 baud, located on the bottom of the serial monitor.
7. Make sure the battery is plugged in and the board is turned on
8. Once the serial monitor is open, there should be a series of “1” scrolling. Press the start button on the Arduino board and after 4 seconds, spin the wheel on your AEV. There should be numbers (marks) increasing or decreasing by 1 and whether the system is moving forward or reverse. If this is not what is seen, go back over *Installing Reflectance Sensors* and check the work. If there are problems that still occur ask an instructional team member for help.
9. Now take the time to orient the sensors appropriately. If the vehicle is moving in the forward direction but the marks are decreasing, then the sensors connections on the Arduino controller need to be switched. Get instructor team verification.

The marks in the serial monitor are similar to how the marks are accumulated in the AEV_Controller code. The goToRelativePostion and goToAbsolutePosition functions were written specifically for this sensor to assist in stopping the vehicle, changing speed, or reversing the rotation of your propeller.

Note: The Arduino will record 8 marks for one full wheel revolution. This is due to four voltage changes (from light to dark to light and back to dark or vice versa) and there are two sensors so therefore there are 8 marks recorded for one full wheel revolution. The wheel has a circumference of ~3.9 inches. Therefore the conversion from marks to distance traveled is **3.9 inches per 8 marks or <u>0.4875 inches/mark</u>**. This will be useful when converting the marks to engineering units of inches.

Sensor Function Calls

- **goToRelativePosition(m);**
  - One Argument; works specifically with reflectance sensor
    - m: Number of wheel marks (from current position)
  - The **goToRelativePosition** function continues the previous command for ***m*** marks from the vehicles current position. ***m*** can be a positive or negative value. A positive values indicates the vehicle is moving forward from its current position. A negative value indicates the vehicle is moving backward from its current position.
  - Example Scenario 1: The vehicle has already traveled 200 marks from the starting point on the track and is stopped at this position. The next lines in the code are:

    motorSpeed(4,20);
    goToRelativePosition(30);

    The code above will set all motors to 20% power and run the motors until the vehicle reaches 230 marks.
  - Example Scenario 2: The vehicle has already traveled 200 marks from the starting point on the track and is stopped at this position. The next lines in the code are:

    reverse(4);
    motorSpeed(4,20);
    goToRelativePosition(-30);

    The code above will reverse all motors, set all motors to 20% power and run the motors until the vehicle reaches mark 170.

- **goToAbsolutePosition(c);**
  - One Argument; works specifically with reflectance sensor
    - c: Number of wheel counts (from current position)
  - The **goToAbsolutePosition** function continues the previous command until the vehicle has traveled to mark ***c*** relative to the starting position of the vehicle.
  - Example Scenario 1: The vehicle has already traveled 200 marks from the starting point on the track and is stopped at this position. The next lines in the code are:

    motorSpeed(4,20);
    goToAbsolutePosition(300);

    The code above will set all motors to 20% power and run the motors until the vehicle reaches 300 marks from the starting point. The equivalent of this using **goToRelativePosition** is:

```
motorSpeed(4,20);
goToRelativePosition(100);
```

- Example Scenario 2: The vehicle has already traveled 200 marks from the starting point on the track and is stopped at this position. The next lines in the code are:

  ```
  reverse(4);
  motorSpeed(4,20);
  goToAbsolutePosition(0);
  ```

  The code above will reverse all motors, set all motors to 20% power and run the motors until the vehicle reaches mark 0 (starting point). The equivalent of this using **goToRelativePosition** is:

  ```
  reverse(4);
  motorSpeed(4,20);
  goToRelativePosition(-200);
  ```

Trouble Shooting

The possible problems that can occur that would cause an uploading error (in order):

1. Check to make sure that the sensors are not mounted too far away from the wheel.
2. Check to make sure that reflectance sensors are installed in the right 3-prong ports on the automatic control system.
3. Check to make sure that the ground wire is the port that is closest to the mini-USB port.
4. Check the actual reflectance sensors by running the "reflectanceSensorTest();" Arduino Code.

Additional Sensor Function Calls

NOTE: The Arduino program, AEV_Controller, can be used to write more complex algorithms to assist in AEV operation. Arduino programming is NOT required for this class thus any experimentation or exploration done is solely the team's responsibility and understanding.

Arduino has a large community that shares programming details and information. For those that would like to dig further the two best places to start learning Arduino is (1) Arduino reference page: http://arduino.cc/en/Reference/HomePage and (2) Googling the question. There are many different sites where Arduino users share helpful programming tips. In addition, there are function calls available to you that may be helpful to use in various ways such as in while loops, for loops, conditional statements, etc. These function calls and details on how to appropriately call them can be found in tab "_00_AEV_key_words" in the AEV_Controller program.

CAUTION: if a loop is call a timing function (like goFor();) must be called within otherwise the data will not be capture (this will be important in later labs)

Example;

```
while (goToAbsolutePosition(m) < 300)
        {
        motorSpeed(1,30);
        goFor(0.5);
        }
```

Once the sensors have been properly installed and tested, verify with an instructional staff before using the zip ties.

After completion of the reflectanceSensorTest code the AEV using the following scenario which should get a typical AEV to the gate system.

OUTSIDE TRACK

1. Run all motors at a constant speed of 25% power for 2 seconds.
2. Run all motors at a constant speed of 20% and using the goToAbsolutePosition function travel a total distance of 16 feet (from the starting point).
3. Reverse motors.
4. Run all motors at a constant speed of 30% power for 1.5 second.
5. Brake all motors.
6. Save the program as ExternalSensorsOutside.

INSIDE TRACK

1. Run all motors at a constant speed of 25% power for 2 seconds
2. Run all motors at a constant speed of 20% and using the goToAbsolutePosition function travel a total distance of 13.5 feet (from the starting point).
3. Reverse the motors.
4. Run all motors at a constant speed of 30% power for 1 second.
5. Brake all motors.
6. Save the program as ExternalSensorsInside.

Once the program has been constructed, **demonstrate the team's program works to an instructional team member** who will look to make sure the propellers are spinning in the correct direction, wires tied away from the propellers, and the sensors work (the instructor would have done this in the reflectanceSensorTest step, and verify the team knows the proper procedure to test the AEV on the overhead track.

Executive Summary

(Due Lab 05: System Analysis 1)

Write an Executive Summary with formatting and content highlighted in the Technical Communications Guide under 'Executive Summary' for specifics.

In addition to the requirements listed in the Technical Communications Guides, be sure to briefly address the following questions. Answer within the summary and be sure not to use numbers or bullets.

- (QUESTION 1) How did the AEV behave on the track? The Arduino code should have made the AEV travel to the gate. Did the AEV that was constructed make it to the gate and stop?

- (QUESTION 2) Explain how the team will utilize the knowledge gained in this lab to construct a preliminary code to complete the scenario stated in the Mission Concept Review (MCR).

Lastly, provide a copy of the External Sensors Arduino Program using the format laid out in the Technical Communications Guide

Grading Rubric – Lab 04: External Sensors

Instructor:____________________ GTA:____________________ Group:_____

Content

					Total
Executive Summary Content	**Purpose**		**Background**		
	3	Good / restated	3	Complete	
	1	Poor / copied	1	Incomplete / not specific	__
	0	Lacking	0	Missing	6
	Objectivity		**Analysis**		
	4	Objective results	5	Clear trends identified	
	2	Some subjectivity	3	Trends unrelated	__
	0	Mostly subjective	0	Not reasoned / verified	9
	Question 1: AEV Behavior		**Question 2: Preliminary Code**		
	6	Justified with data and observations	6	Justified with data and theory	
	3	Justified, incomplete data or observations	3	Justified, incomplete data or theory	
	2	Not fully reasoned / verified	2	Not fully reasoned / verified	___
	0	Missing	0	Missing	12
	Resolving Error		**Recommendations**		
	5	Addresses error / reasonable	5	Reasonable & 2 or more	
	3	Unaddressed or unreasonable	3	Somewhat lacking	
	2	Lacking thought	2	Not fully reasoned	___
	0	Missing	0	Missing	10
	Conclusions		**Copy of Arduino Code**		
	5	Relevant & supported	3	Attached / Commented / Correct	
	3	Unsupported / irrelevant	2	Attached / Missing Section(s)	
	2	Very lacking	1	Very Lacking	___
	0	Missing	0	Missing	8

Content Total / 45

Format & Language

Total

Content	Content	
	4	Appropriate content
	2	Excess content / vague details
	0	Vast excess content / content very vague

__ / 4

Labels & References	Labels		Referencing	
	3	All present with good label descriptions	3	Well referenced & described in body
	2	Some missing or poor descriptions	2	Poor descriptions and/or references
	0	Missing or no description	0	Missing references

__ / 6

General Format	Errors	
	4	Fewer than 2 mistakes
	2	2-5 mistakes
	0	More than 5 mistakes

__ / 4

Structure	Brevity		Clarity		Flow	
	4	Concise	3	Clear	4	Smooth
	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed

__ / 11

Wording	Professionalism		Tense / Person	
	3	No slang, jargon, etc.	3	No slips in tense/person
	2	Some slips in professionalism	2	1-3 slips in tense/person
	1	Distracting / poor	1	4-8 slips in tense/person
	0	Exceedingly poor	0	More than 8 errors

__ / 6

General	Spelling / Grammar / Punctuation	
	4	Minor errors
	3	Few errors, but not distracting
	1	Distracts from readability
	0	Complete lack of proofreading

__ / 4

Writing Total / 35

Content Total / 45

Total / 80

Instructor/ GTA End-of-Lab Signoff

Lab 4: ______________________________________

Lab 05: System Analysis 1 – Propulsion Efficiency

Objectives

1. Become familiar with propulsion system efficiency
2. Become familiar with wind tunnel testing equipment
3. Relate AEV to real-life objects
4. Link wind tunnel testing to the AEV

Lab Equipment

1. Wind Tunnel
2. Propeller and motor (already installed in the wind tunnel)
3. Clipboard
4. Wind Tunnel Testing Sheet

Background

Efficiency, in the context of this project, is the ability of a system to avoid wasting energy. The efficiency of a system can be measured quantitatively by taking the ratio between the useful power output and the total input power. For example, the input power for the AEV is the lithium-ion battery and the output power is the thrust created by the propeller and motor combination. Thus, the *propulsion efficiency* of an AEV is a combination of the *motor efficiency* and *propeller efficiency.*

The propulsion efficiency can vary from vehicle to vehicle from the difference between the motors (i.e., internal friction, torque, speed) and the types of propellers (i.e., blade angle, size, blade design) used. Since testing of various motors can be expensive (and unnecessary for this project), testing varying propeller designs can be an effective way to improve the overall design and energy consumption of an AEV. A common testing procedure used to measure propulsion efficiency in Aerospace engineering is wind tunnel testing.

Wind tunnel testing is important for the AEV in the decision making process by determining the propeller, the propeller configuration, and the most energy efficient operating condition. This same methodology was used in creating the Piaggio Avanti, one of the world's most propeller driven aircraft. That aircraft was created by a team of engineers' right here at The Ohio State University.

The following figure shows the wind tunnel and testing equipment that are needed for the lab. This includes the wind tunnel, speed controller, power supply, thrust stand, and data acquisition system. The wind tunnel simulates an AEV in motion without having all the AEV, but just the propeller and motor. The wind tunnel can control the velocity of the AEV and also provide a means to instrument the propulsion system (propeller and motor). The wind tunnel is an easier system to instructor and control and trying to instrument each and every AEV.

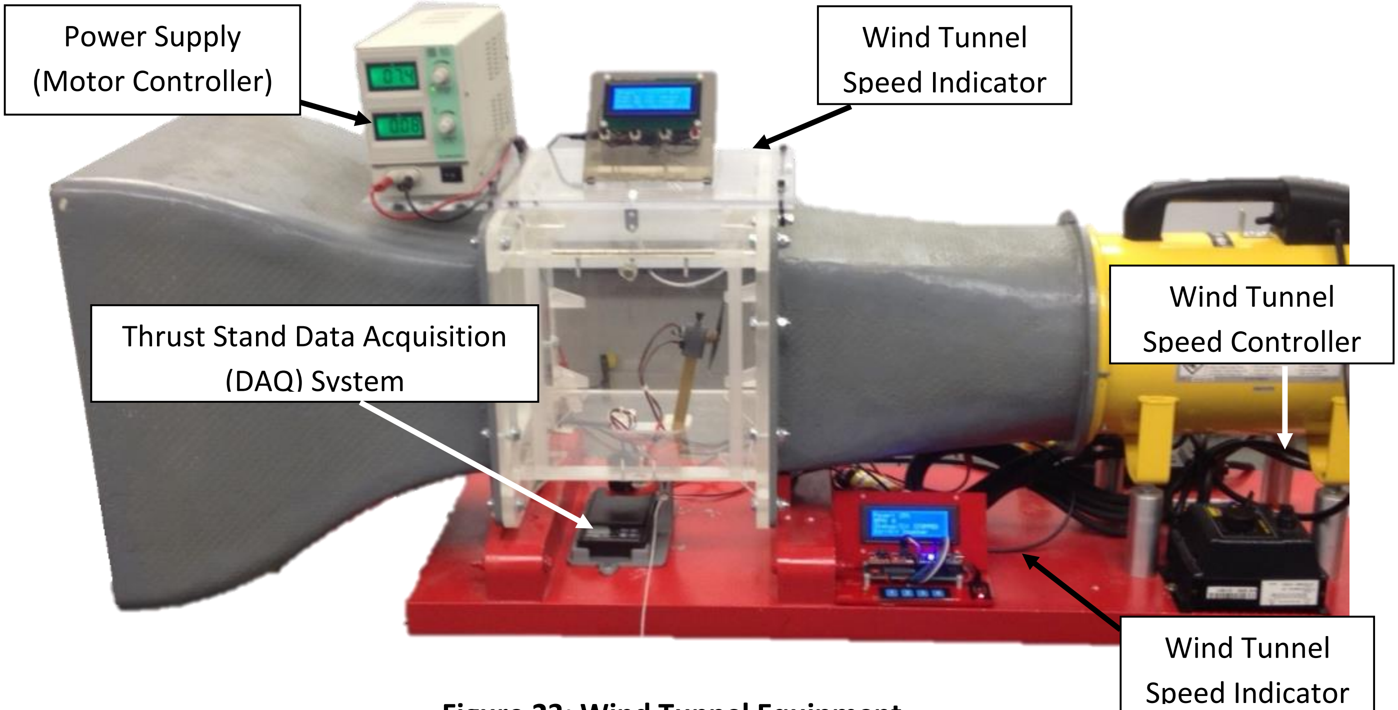

Figure 23: Wind Tunnel Equipment

The goal is to determine how efficient the propulsion system is by (1) setting the input power (voltage and current) supplied to the motor, (2) measuring the power output from the electric motor and the propeller using a thrust stand. The propulsion efficiency is the ratio of the input and output power.

$$Propulsion\ Efficiency(\%) = \frac{Output\ Power}{Input\ Power} * 100$$

The output power for the AEV is a function of three variables; vehicle velocity (v), propeller RPM, and the diameter (d) of the propeller used. To combine all these independent variable into something the investigator can study, a dimensional analysis can be conducted to obtain a singular variable. This dimensional analysis comes from the Buckingham π Theorem. So for the propeller's output power the non-dimensional unit that derived from this theorem was the Propeller Advance Ratio (J).

$$Propeller\ Advance\ Ratio\ (J)\ \frac{Velocity\ (v)}{\left({}^{RPM}/_{60}\right) * Diameter\ (d)} * 100$$

The units of J are non-dimensional. To measure the power available (output) from the electric motor and propeller, a calibrated thrust stand will be used to measure thrust for known settings of input power, by incrementing the voltage and recording the voltage and current supplied to the electric motor from the power supply.

Recall that the efficiency, hence the power available, is a function of velocity and propeller RPM. The wind tunnel will be used to control the simulated velocity of the AEV, and known propeller RPM characteristics with the current supplied by the power supply, to calculate the propeller advance ratio. The thrust available will be measured and the power available calculated using the wind tunnel speed. This ultimately obtains the propulsion efficiency for AEV's propulsion system.

In this lab, there will be multiple wind tunnels in the front of the classroom. Each wind tunnel will have a different ***propeller configuration.*** Propeller configuration is an important aspect to consider in the team's AEV design. There are two classifications of propeller configuration. There is the (1) tractor (or puller) configuration and (2) the pusher configuration. See Figure 24 and Figure 25 respectively. The thrust line in the figures below means that the direction an AEV would travel NOT where air is felt.

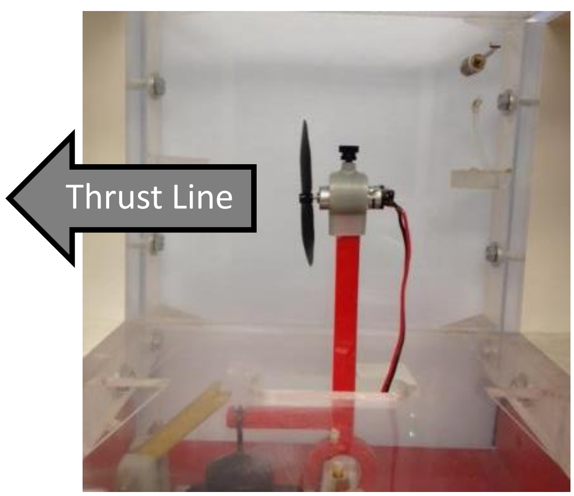

Figure 24: Electric Motor Mounted in Puller (tractor) Configuration

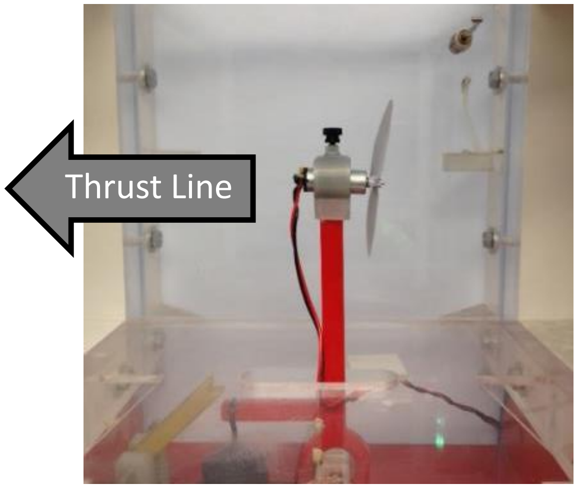

Figure 25: Electric Motor Mounted in Pusher Configuration

Lab Activity

The following procedure will help the team set up and conduct the wind tunnel test.

1. When the team is called up to the wind tunnel, one team member should bring a printed copy of the Appendix D – Wind Tunnel Spread Sheet spread sheet and a pen/pencil (located on both the website and in Appendix D – Wind Tunnel Spread Sheet.
2. Verify which configuration you are working with by writing down either "pusher" or "puller" on the wind tunnel spread sheet.
3. Turn on the power supply. Verify that the voltage on the power supply reads 7.4 volts and the current knob is turned all the way clockwise. Note: The 7.4 voltage setting is representative of what a fully charged battery would supply to the Arduino Motor controller.

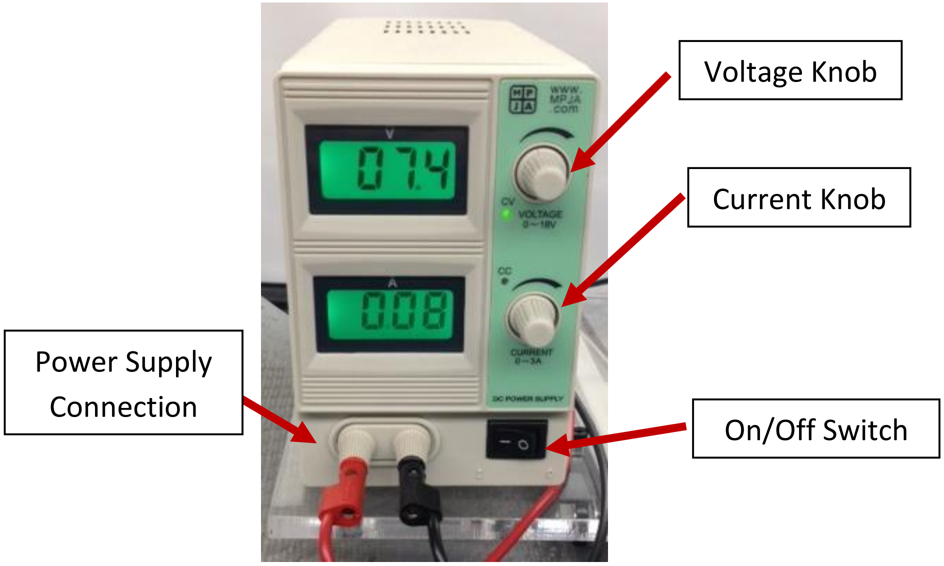

Figure 26: Power Supply Connection

4. Turn on the Thrust Stand Data Acquisition System (DAQ) (see Figure 27).

Figure 27: Thrust Stand Data Acquisition (DAQ) System

5. Unlock the moment arm so that the arm is resting on the scale. DO NOT REZERO THE SCALE AT THIS POINT. See Figure 28.

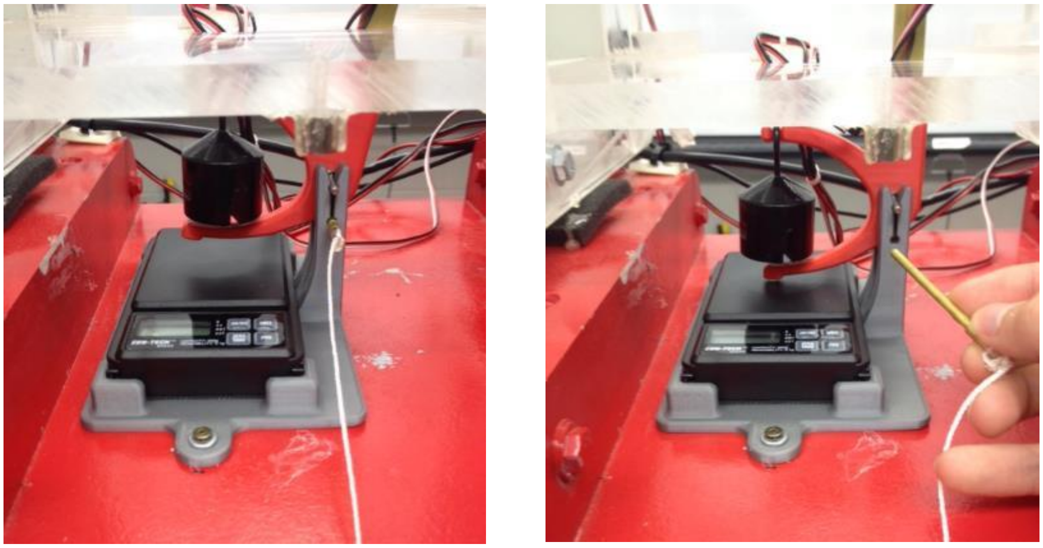

Figure 28: Moment arm disengaged (LEFT) and Moment arm engaged (RIGHT)

6. Turn on the wind tunnel speed controller. See Figure 29 (left image) below.
7. Verify that the velocity speed indicator is set to approximately ~2.8 meters/sec. Note: this number does not need to need to be exact, so do not spend a lot of time trying to obtain this value). See Figure 29 (right image) below. After this value has been set do not worry about it during testing as the propeller will affect the value.

Figure 29: Wind Tunnel Speed Control (LEFT) and Velocity Speed Indicator (RIGHT)

8. Take an initial reading. Record the (1) percent power, (2) current, and (3) thrust scale reading. This value will be used to reference zero.
9. The Arduino Control System (see Figure 30) will control the power supplied to the motor. The (1) button increases the percent power in 5 percent increments. The (2) button decreases the percent power by 5 percent increments. The (3) supplies and cuts power to the motor. The (4) button changes the direction the propeller rotates.

Figure 30: Arduino Control System

10. Check that the propeller is rotating in the right direction.
    a. Set the power to 25%.
    b. Look very carefully at the propeller. As the (3) button is pushed, determine if the propeller is rotating counterclockwise.
    c. Push the (4) button to reverse the direction of the propeller if needed.
11. On the Arduino Control System, push the (1) button until the Power reads 60%.
12. By selecting the (3) button, this will supply power to the propeller.
13. Take a reading [(1) percent power, (2) current, (3) thrust scale reading and (4) RPM] at each power setting going from 60% to 10% in 5% increments. Use the (2) button to decrease the power in 5% increments.
14. When the team reaches 10 % power press the (3) button to cut power to the motor. Turn off the wind tunnel and the power supply.
15. Look at the data, the thrust should be decreasing in value from 60% down to 10%. If it is not, then the propeller was not spinning in the correct direction providing the team with null results.

After the wind tunnel testing is completed clean up around the area for the next team. Continue with the following procedure to analyze the wind tunnel test results. Once the data is collected turn off Arduino Control System and disengage the moment arm.

Wind Tunnel Data Analysis

The thrust stand set up uses a 200 gram counter weight. Since there was a counter weight was used in the wind tunnel set up and the motor was attached on a moment arm (and not set on the scale, this needs to be accounted for in the thrust reading). To obtain the true thrust of the propulsion system the following equation for the thrust calibration is:

$$T_c = 0.411 * (T - T_0)$$

where: T_c = Calibrated Thrust (grams)
T = Thrust scale reading (grams)
T_0 = Thrust scale reading at 0% power (grams)

The 0.411 is a correction factor determine from a straight-line pull method. This linear relationship is used because of the counter weight and the moment arm used, and to verify that the thrust measured is what the propulsion system is producing (example 1 gram read on the Thrust stand DAQ system is 1 gram produced by the propulsion system). The input power supplied to the electric motor is determined by the voltage and current recorded and the power setting.

Power Input: $$P_{in} = V * I * (P_{\%} / 100)$$

where: P_{in} = power input (watts)
V = voltage (volts)
I = current (amps)
$P_{\%}$ = Arduino Power Setting

The power available (output) is measured by the velocity at which the vehicle is moving and the thrust required to create that movement. *NOTE: See the conversions below this formula for calculating the output power correctly.*

Power Available: $$P_{out} = T_c * v$$

where: P_{out} = power available (watts)
T_c = calibrated thrust (Newton)
v = wind tunnel velocity (m/s)

In order to compute the output power correctly, the product of the thrust (***recorded in grams, not newtons***) and the wind tunnel velocity (m/s) can be converted to watts using the following unit conversions below. Notice that even though typically mechanical systems express power in units such as horsepower they can easily be converted to watts.

1 gram = 0.002205 lbs.
1 m/s = 3.28 ft/s
1 horsepower = 550 lb*ft/s
1 horsepower = 745.7 watts

Or convert the measured value of thrust in grams to force by multiplying by the acceleration due to gravity.

Thrust = m*a (Newton)
m = mass (kg)
a = acceleration due to gravity = 9.81 m/s^2

Now multiplying the thrust (in Newtons) by the wind tunnel velocity (m/s) will result in the output power in watts.

Now determine the propulsion system efficiency for your electric motor and propeller.

Propulsion Efficiency:

$$\eta_{sys} = \frac{P_{out}}{P_{in}} \times 100\%$$

Multiply the efficiency by one-hundred to determine the efficiency in percentage.

In order to update the energy analysis spreadsheet from System Analysis 2 with your own propulsion system characteristics, closing the loop between supplied power and energy & power and energy output, the non-dimensional propeller advance ratio from the wind tunnel tests must be calculated. The advance ratio equation is as follows:

Propeller Advance Ratio:

$$J = \frac{v}{(RPM/60) * D}$$

where: v = velocity (meters / sec.)
RPM = propeller RPM
D = propeller diameter (meters)

The velocity was simulated by the wind tunnel, and set a constant value of 2.8 meter/sec. In order to determine the propeller efficiency as a function of the advance ratio, make a plot of efficiency (y-axis) and advance ratio (x-axis). A sample of the plot is seen in Figure 31.

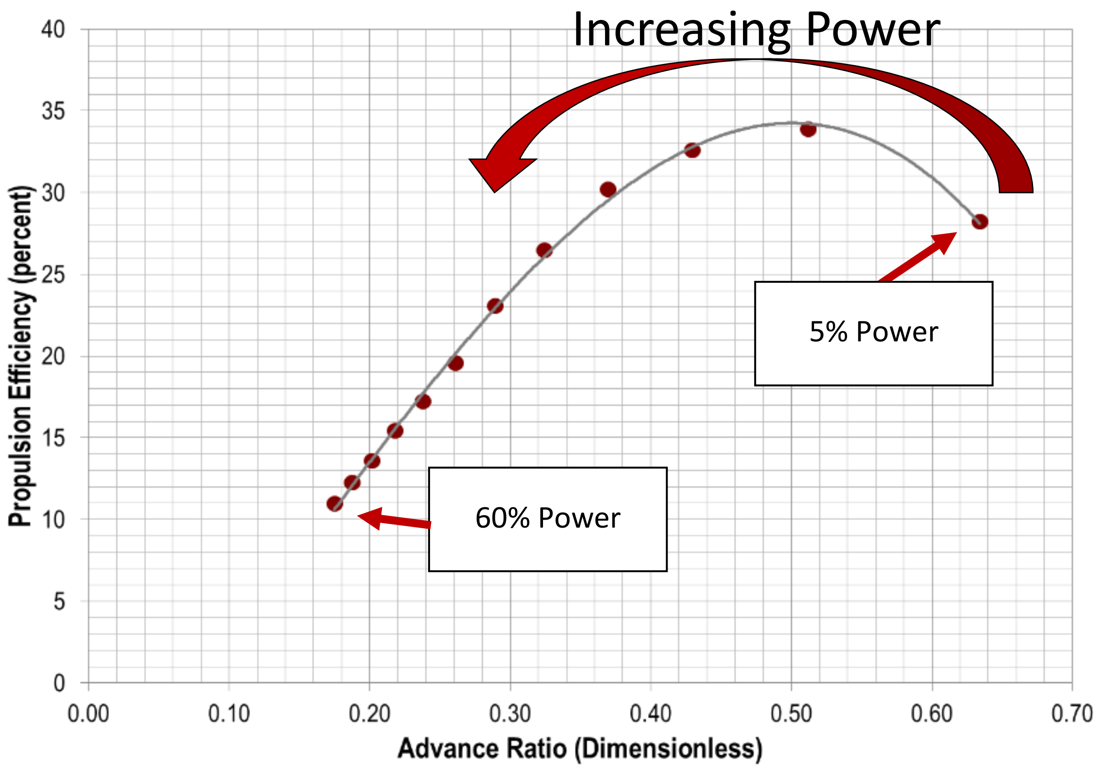

Figure 31: Example of Propulsion Efficiency versus Advance Ratio for a propeller

Upon investigation of the creation of the plot it can be noted how it is created right to left where at 5% power is the far right most point and 60% power is the far left most point. With this knowledge the team should start to think about the propulsion efficiency of the AEV vehicle to minimize energy use. For the mystery propulsion (motor + unknown propeller) used in Figure 31, the maxima occurs around a percent power of approximately 11% power with a 35% propulsion efficiency. So to have an propulsion efficient AEV, the power would need to be set at say 'motorSpeed(4,11);' and in turn would require a lesser amount of power from the battery. Though a few questions remain, does this provide enough power to get an AEV moving? Would this give the AEV enough speed to finish the Mission in the allotted time?

Executive Summary

(Due Lab 06: System Analysis 2)

Write an Executive Summary with formatting and content highlighted in the Technical Communications Guide under 'Executive Summary' for specifics.

In addition to the requirements listed in the Technical Communications Guides, be sure to briefly address the following questions. Discuss the results of the lab by explaining how this lab can aid in the team's programming strategy and design. Refer to figures and tables constructed during and after the lab in the discussion.

- Provide the following figures and tables:
  - A table or tables containing Wind Tunnel Data with appropriate labeling and indicated propeller and motor configuration.
  - A plot or plots of Thrust (Grams) vs. % power for each propeller type used.
  - A plot or plots of Propulsion Efficiency vs. Advance Ratio. Indicate propeller type used.

- Provide an explanation for the figures and tables and what they are representing.

- (QUESTION 1) Looking at all the different propeller results, how will this aid in the team's decision on propeller? Justify the team's answer.

- ***Individually:*** Sample calculations for power input and output, calibrated thrust, advance ratio, and propulsion efficiency for a single point. Indicate in what section of the code the sample calculations are being performed. (Again, this is done individually on a separate Microsoft Word page and attached in the Appendix with each individual team member's name.

- Lastly, provide a copy of the System Analysis 3 Wind Tunnel Raw Data (Thrust, Current, and Voltage) in the Appendix.

Grading Rubric – Lab 05: System Analysis 1

Instructor:____________________ GTA:____________________ Group:______

Content

Executive Summary Content	Purpose		Background		Total
	3	Good / restated	3	Complete	
	1	Poor / copied	1	Incomplete / not specific	
	0	Lacking	0	Missing	__ 6
	Objectivity		**Analysis**		
	4	Objective results	5	Clear trends identified	
	2	Some subjectivity	3	Trends unrelated	
	0	Mostly subjective	0	Not reasoned / verified	__ 9
	Figures and Tables with Explanations		**Question 1 (Propeller Choice)**		
	8	All 4, properly labeled, explained	3	Justified with data and theory	
	5	Missing 1/not fully explained	2	Justified, incomplete data or theory	
	2	Not fully reasoned / missing 2+	1	Not fully reasoned / verified	
	0	Missing	0	Missing	___ 11
	Resolving Error		**Recommendations**		
	5	Addresses error / reasonable	5	Reasonable & 2 or more	
	3	Unaddressed or unreasonable	3	Somewhat lacking	
	2	Lacking thought	2	Not fully reasoned	
	0	Missing	0	Missing	___ 10
	Conclusions		**Copy of Raw Wind Tunnel Data**		
	5	Relevant & supported	3	Attached / Correct	
	3	Unsupported / irrelevant	2	Attached / Missing Data	
	2	Very lacking	1	Very Lacking	
	0	Missing	0	Missing	___ 8

Content Total / 44

Format & Language

Content	Content		
	4	Appropriate content	
	2	Excess content / vague details	
	0	Vast excess content / content very vague	__ / 4

Labels & References	Labels		Referencing		
	3	All present with good label descriptions	3	Well referenced & described in body	
	2	Some missing or poor descriptions	2	Poor descriptions and/or references	
	0	Missing or no description	0	Missing references	__ / 6

General Format	Errors		
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Writing Total / 35

Content Total / 44

Instructor/ GTA End-of-Lab Signoff

Lab 5: ______________________________

Individual Content

A	Power Input/Output		Calibrated Thrust		Advance Ratio		Propulsion Efficiency		Total
Appendix (Sample Calculations)	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	
	3	Incorrect result but right formula	3	Incorrect result but right formula	3	Incorrect result but right formula	3	Incorrect result but right formula	___ 16
	2	Poor	2	Poor	2	Poor	2	Poor	
	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	A

Student Name: ____Total /95

Individual Content

B	Power Input/Output		Calibrated Thrust		Advance Ratio		Propulsion Efficiency	
Appendix (Sample Calculations)	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units
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	2	Poor	2	Poor	2	Poor	2	Poor
	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten

____ 16

B

Student Name: ____Total /9

Individual Content

C	Power Input/Output		Calibrated Thrust		Advance Ratio		Propulsion Efficiency		
Appendix (Sample Calculations)	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	
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	2	Poor	2	Poor	2	Poor	2	Poor	
	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	C

Student Name: ____Total /95

Individual Content

D	Power Input/Output		Calibrated Thrust		Advance Ratio		Propulsion Efficiency		
Appendix (Sample Calculations)	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	
	3	Incorrect result but right formula	3	Incorrect result but right formula	3	Incorrect result but right formula	3	Incorrect result but right formula	___ 16
	2	Poor	2	Poor	2	Poor	2	Poor	D
	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	

Student Name: ____Total /95

Lab 06: System Analysis 2 – Performance Data Analysis

Objectives

1. Be able to download data from the automatic control system.
2. Be able to convert EEPROM Arduino data to physical parameters.
3. Be able to calculate performance characteristics using physical parameters.

Lab Equipment

1. Constructed AEV
2. USB Cable
3. Battery

Background

Measuring and evaluating the performance of an AEV post-run is an important tool that can be used in the design process. The AEV controller is recording data as the vehicle is running (approximately every 60 milliseconds) using EEPROM (Electrically Erasable Programmable Read-Only Memory) on the Arduino Nano. The kind of data recorded includes:

- EEPROM time, t_E, Time in milliseconds,
- Current, I_E, supplied to the electric motors in *ADC counts*,
- Voltage, V_E, supplied to the electric motors in *ADC counts*,
- Wheel Counts from the reflectance sensors.

Where the subscript *E* denotes EEPROM measurements and the acronym *ADC* stands for *Analog to Digital Conversion.* Arduino uses ADC to store current and voltage readings dividing the voltage range of 0 to 5 volts into 1,024 different voltage levels. Thus, the range of ADC counts that the EEPROM current and voltage will be in will be 0 - 1,023. EEPROM measurements. For more information on *Analog to Digital Conversion, see the Arduino web page on Analog Input.*

Once an AEV is completed (i.e., the program loaded on the AEV has completed) the EEPROM data recorded during the AEV run can be downloaded using MATLAB. Given a set of EEPROM data from an AEV run, the EEPROM data can be converted to physical parameters (provided in the lab activity) and performance characteristics such as input power to the AEV, energy consumption of the AEV, distance traveled and vehicle velocity can be calculated. This data, coupled with observations of the AEV performance on the track, can aid in further design modifications and operational modifications needed for improvement of the AEV (i.e., determining where reductions in power supplied to the motors can be made).

Lab Activity

Develop a program for an AEV test run

1. As a team, develop a program that will allow the AEV to travel from the starting point to the first stop, just before the gate. Some hints and tips before running the AEV on the track:
    a. Check the balance of the AEV with the battery.
    b. Use the monorail schematic provided in the Mission Concept Review (MCR) to determine the distance required to travel.
    c. Do a trial run on the track with a low power setting (15%-20% power). Increase the power setting in 2%-3% increments if needed.
    d. **CAUTION**: Vehicles can fall off the track from traveling too fast and/or being unbalanced. The team shares the responsibility of ensuring your classmates safety with the whole class.
2. Once the program has been constructed, demonstrate the team's program works ***statically*** (using the desktop stands) to an instructional team member. The goal is to make sure the code was properly installed, the AEV would travel in the correct direction, and demonstrate proper testing procedure as highlighted in the Testing Procedure.
3. **Get verification from the instructional team member to test on the classroom track.**
4. NOTE: When your vehicle has completed a run on the track, the yellow LED will blink 10 times and then turn on. The Arduino is still collecting data up until the LED is done blinking. ***Make sure the AEV is not turned off until the yellow LED is done blinking and on again! You will lose all data recorded during the run.***

Downloading Arduino EEPROM Data

To download data from the automatic control system, follow these steps:

5. First and foremost, after the AEV program is done running turn **off** the power to conserve battery life (this is **AFTER** the yellow light becomes solid again (after 10 flashes), else all the data will be lost!).
6. On the desktop computer (pick a team member's desktop to use), open the sketchbook folder and open the **aevDataRecorder** program in MATLAB. **aevDataRecorder** is a MATLAB function file that will extract the Arduino data recorded during an AEV run. The data is saved in the following variables:
    a. te: EEPROM time (milliseconds)
    b. ie: EEPROM current (ADC counts)
    c. ve: EEPROM voltage (ADC counts)
    d. marks: Cumulative wheel counts from the reflectance sensors
    e. pos: Wheel counts from the reflectance sensors indicating **pos**ition on track.

   The **aevDataRecorder** function will save these variables in a MAT-File. MAT-Files are binary MATLAB format files that store workspace variables.

7. Connect the Arduino controller to the computer using the mini-USB cord. The yellow or white LED on the Arduino should flash several times before turning solid. If the LED is not turning solid, ask an instructional team member for help.
8. Run the aevDataRecorder and save the MAT-File as ***performance_analysis_1***. There are one of two ways to use the aevDataRecorder function provided.
    i. Type aevDataRecorder in the MATLAB command window:
        - No input needed. The program will ask the user for a file name and the user can save the file anywhere outside the MATLAB directory.
    ii. Pressing the Run button in the editor toolbar menu.
        - Executes the function just as first method described.
9. When the user calls the aevDataRecorder function the program will indicate in the command window what steps it is going through. When the program indicates it is finished it has been successfully downloaded the Arduino EEPROM data and saved it to a MAT-File.
10. Ask for help from an instructional team member if any errors occur.

Converting EEPROM Data to Physical Parameters

11. As a team, write a MATLAB script file that will do the following:
    a. Load the EEPROM data into the MATLAB workspace.
    b. Convert EEPROM time (te), current (ie), voltage (ve), marks (marks), and positions (pos) to physical parameters. See conversions below.

A template of what the header of the script file should look like is shown in Figure 32.

```
%=======================================================================
% Name:
% Date:
% Class:
%
% Program Title: Performance Analaysis
%
% Program Description: Add a description of the program here.
%
%=======================================================================

% Load EEPROM data into MATLAB workspace
load('performance_analysis_1')

```

Figure 32: Example MATLAB Script File

The following microprocessor conversion equations are used to convert the EEPROM equivalent data to the physical parameters of time (sec.), current (amps), voltage (volts), distance (m) and position (m).

Time: $$t = \frac{t_E}{1000}$$

where: t = time (seconds)
t_E = EEPROM time (milliseconds)

Current: $$I = \left(\frac{I_E}{1024}\right) * V_R * \left(\frac{1\,\text{Amp}}{0.185\,\text{Volts}}\right)$$

where: I = current (amps)
I_E = EEPROM current (ADC counts)
V_R = 2.46 volts = Arduino reference voltage

Voltage: $$V = \frac{15 * V_E}{1024}$$

where: V = voltage (volts)
V_E = EEPROM voltage (ADC counts)

Distance: *d = 0.0124*marks*

where: d = distance (meters)
$marks$ = wheel counts accumulated by reflectance sensors

Position: *s = 0.0124*pos*

where: s = AEV position (meters from starting point)
pos = wheel counts recorded by reflectance sensors

Performance Analysis

Now that the EEPROM data is converted into physical parameters, the next step is to analyze the data to determine important parameters relevant to operating the AEV.

1. For the first performance analysis activity, this includes calculating the power and energy supplied to the vehicle. First calculate the power (watts) supplied to the vehicle using the voltage and current (in the same performance_analysis_1 script file).

Power: $$P = V * I$$

where: P = Input power (watts)
V = voltage (volts)
I = current (amps)

The supplied energy (joules) is a function of the supplied power (watts) and time (sec.). The energy supplied to the AEV can be thought of as both the incremental energy, similar to the incremental power, and the total energy supplied throughout the entire AEV operation. The amount of energy used corresponds to the area under the curve of power-time plots, with power on the y-axis and time on the x-axis. The method used to determine the energy will be using a rectangular approximation of the power and time data. There are three approximation methods that use neighboring data points for both power and time, they include: left-end point, right-end point, and midpoint (shown below).

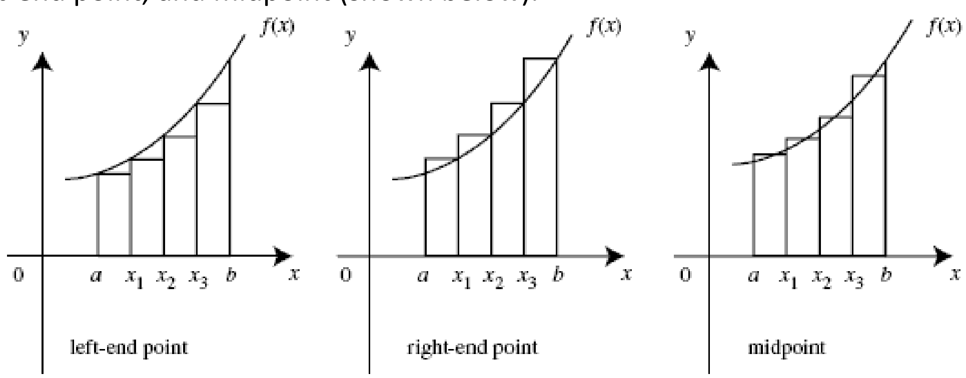

Figure 33: Rectangular Approximate Method

In the above figure, the f(x) corresponds to P(t).

2. Using the *midpoint method*, the incremental energy areas can be determined by averaging the power of two neighboring points and multiplying by the time increment from point one to point two. This is shown below:

Incremental Energy: $$E_j = \frac{P_j + P_{j+1}}{2} * \left(t_{j+1} - t_j\right),$$ for *j = 1,…,N-1*

where *N* = total number of elements in *P.*

The total energy used during the AEV run corresponds to the sum of all of the incremental energies.

Total Energy: $$E = \sum_{n=1}^{N-1} E_n$$

Plotting Performance Analysis

During an AEV run, the program is recording data (time, current, voltage, distance and position) every 60 milliseconds. When a run could take up to 1-2 minutes, the amount of data the team will be working with can be a lot (up to ~2,000 data points for a 2 minute run). Plotting and visualization is very useful for seeing where the AEV is consuming a lot of energy during a run for instance.

In the same script file (performance_analysis_1), perform the following tasks:

1. Create a plot of the supplied power (Watts) vs. time (seconds) with the following:
   A. A line width of 2.
   B. X and Y labels.
   C. Grid on.
   D. Box on.
   E. An appropriate title for the plot.

2. Create a separate power-time plot dividing it into "phases" that represent the uses of power based on your Arduino commands. See, for example, Table 4 and Figure 34.

   Do the following:
   1. Divide your plot into phases. Hint: In the MATLAB figure window use Insert -> Rectangle to draw the boxes defining the separate phases of the AEV run. Once the box is drawn, right-click on the box and the color, line-width, and line style can be modifed. The rectangles should have the following:
      a. Linewidth of 3.
      b. Dash linestyle.
      c. Colors of the team's choosing.

      Text can be added to the plot using Instert -> TextBox. Make the font size appropriate and set the linestyle to "none" to remove the line around the text.

   2. Select the boundary points of the phases on the plot (see Figure 34 below for screenshot explanation).

3. Select the **boundary points of the phases** on the plot and find the value of the points (X=time, Y=power). Hint: Use the ***Data Cursor*** tool in the figure toolbar. Select a single point by selecting points on the power-time curve. A text box will appear displaying the x and y values.

4. Calculate energy used adding the incremental energy column between those 2 times. An example algorithm for Phase 1 that can be used in the MATLAB script file is provided below. The algorithm uses a MATLAB built-in function called "knnsearch". For example, idx = knnsearch(x,y) finds the location in a vector (or matrix) x that is closest to y.

```
% Phase 1
xR = enter right coordinate here;  % Right x-coordinate
xL = enter left coordinate here;   % Left x-coordinate
iL = knnsearch(t,xL);              % Element index of left point
iR = knnsearch(t,xR);              % Element index of right point
P1 = P(iL:iR);                     % Power values of Phase 1
t1 = t(iL:iR);                     % Time values of Phase 1

% Compute incremental energy of Phase 1

% Compute total energy of Phase 1
```

5. Create a table that has a breakdown of supplied energy for each line of code of the AEV's operation (each phase of the vehicle's motion that consumes energy) and the total supplied energy. The break down should include, but is not limited to: accelerating portions, constant speed portions, decelerating portions, etc. If necessary, indicate on the table if the motors have been reversed for a portion of the supplied energy.

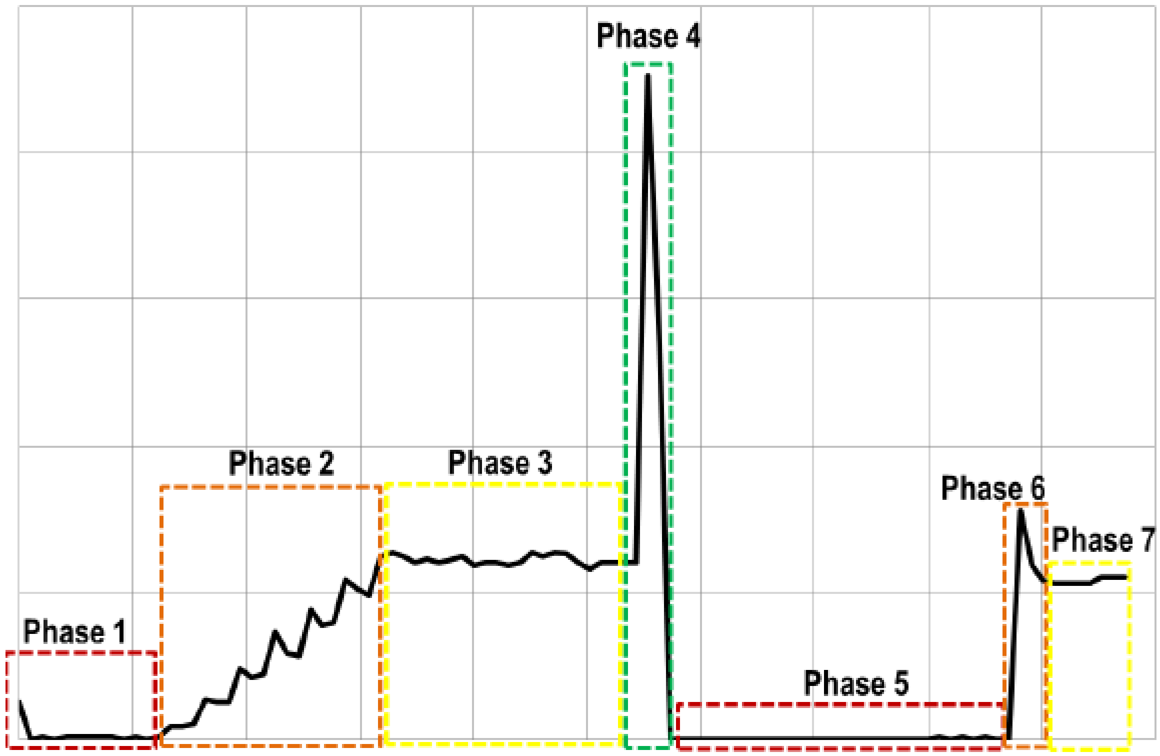

Figure 34: Example of phase breakdown (Do not forget labels on the axis!)

Table 4: Example of table for phase breakdown

Phase	Arduino Code	Time (seconds)	Total Energy (Joules)
1			
2			
3			
4			
5			
6			
7			
		Total Energy Used:	

Note: There is no right or wrong way to break up the phasing, as long as there is a reasoning why it was broken up the way it was with the appropriate Arduino code with each phase.

Executive Summary

(Due Lab 07: Design Analysis Tool)

Write an Executive Summary with formatting and content highlighted in the Technical Communications Guide under 'Executive Summary' for specifics.

In addition to the requirements listed in the Technical Communications Guides, be sure to briefly address the following questions. Discuss the results of the lab by explaining how this lab can aid in the team's programming strategy and design. Refer to figures and tables constructed during and after the lab in the discussion.

- Provide the following figures and tables:
    - A plot of Supplied Power (Watts) vs. Time (seconds)
    - A plot with a phase breakdown
    - A table of the phase breakdown consisting of the following:
        - *Phase*
        - *Arduino Code*
        - *Distance*
        - *Time*
        - *Total Energy used each phase*

Note: The figure and table DOES NOT HAVE TO LOOK LIKE Figure 34 *AND* Table 4: Example of table for phase breakdown*! There could be 3 phases due to the team's coding strategy or there could be 20 phases! There is no right or wrong answer as long as there is justification behind the phases.*

- (QUESTION 1) Looking at the plot(s) how will this aid in the team's coding strategy? Justify the team's answer.

- ***Individually:*** Sample calculations for time, distance, position, current, voltage, supplied power, and incremental energy for a single point in the code. Indicate in what section of the code the sample calculations are being performed (Again, this is done individually on a separate Microsoft Word page and attached in the Appendix with each individual team member's name).

Lastly, provide a copy of the System Analysis 2 Arduino Code in the Appendix using the format laid out in the Technical Communications Guide. **Do not forget to do Bonus Video Part 1 (Due Lab 07: Design Analysis Tool) if the team wants extra credit!!**

Grading Rubric – Lab 06: System Analysis 2

Instructor:____________________ GTA:____________________ Group:_____

Content

Executive Summary Content					Total
	Purpose		**Background**		
	3	Good / restated	3	Complete	
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	Conclusions		**Copy of Arduino Code**		
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A	/ 95	B	/ 95
C	/ 95	D	/ 95

Instructor/ GTA End-of-Lab Signoff

Lab 5: ________________________________

Individual Content

<table>
<tr><th>A</th><th colspan="2">Time/Distance/Position</th><th colspan="2">Current/Voltage</th><th colspan="2">Supplied Power</th><th colspan="2">Incremental Energy</th><th>Total</th></tr>
<tr><td rowspan="4">Appendix (Sample Calculations)</td><td>4</td><td>Indicated data, provided and applied formula, units</td><td>4</td><td>Indicated data, provided and applied formula, units</td><td>4</td><td>Indicated data, provided and applied formula, units</td><td>4</td><td>Indicated data, provided and applied formula, units</td><td rowspan="4">___
16
A</td></tr>
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</table>

Student Name: ____ **Total /95**

Individual Content

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	2	Poor	2	Poor	2	Poor	2	Poor	
	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	B

Student Name: ____ **Total /95**

Individual Content

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Student Name: ____ **Total /95**

Individual Content

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Appendix (Sample Calculations)	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units	4	Indicated data, provided and applied formula, units
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	2	Poor	2	Poor	2	Poor	2	Poor
	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten	0	Missing / Handwritten

___ / 16

D

Student Name: ____

Lab 07: Design Analysis Tool

Objectives

1. Become familiar with MATLAB based design analysis tool.
2. Be able to upload wind tunnel data into the design analysis tool.
3. Be able to upload Arduino data into the design analysis tool.
4. Be able to conduct performance analysis of an AEV operation.
5. Be able to export plots for reports.

Lab Equipment

None

Background

At points during the design process, repetitive tasks involving programming and calculations for analysis of a system can consume time. Automating tasks such as the performance analysis calculations can be done in a variety of ways. Here, a MATLAB Graphical User Interface (GUI) is provided that is an all-in-one tool for (1) downloading Arduino data, (2) performing performance analysis calculations, (3) plotting results, etc.

The goal of this lab is to learn how to use a design analysis tool that provides an efficient and productive method to evaluate AEV performance. This program was designed to communicate with the Arduino motor controller, which will download data collected from the Arduino motor controller after an AEV test run. The following describes in detail how to use the AEV Analysis program.

Lab Activity

Installing and Running the Design Analysis Tool

NOTE: This application will **<u>only work on Windows computers with MATLAB 2015</u>** and earlier (provided on all computers in Hitchcock). The following steps are for installation of the AEV Analysis tool for both home computers and computers in the class room.

1. Download the AEV Design Analysis Tool zip file located on the AEV Documents web page. Extract the contents of the zip file. In the Design Analysis Tool folder, click into the Design Analysis Tool folder and double click on the install app called **"AEV_Analysis_Tool.mlappinstall"**. MATLAB will open if it is not already running and display the window shown in Figure 35.

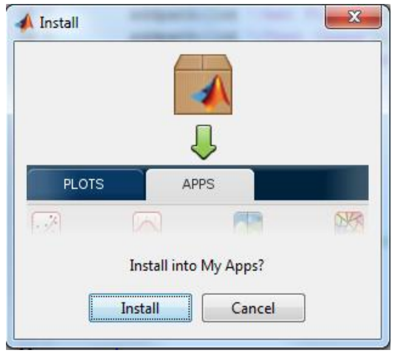


Figure 35: MATLAB Installer

2. Click on the “Install” button and MATLAB will install the AEV Analysis tool in the Apps bar.
3. To view the App, select the “App” tab, then select the down arrow on the far right of the menu and you will see the “AEV Analysis” app installed under “My Apps”. See Figure 36.

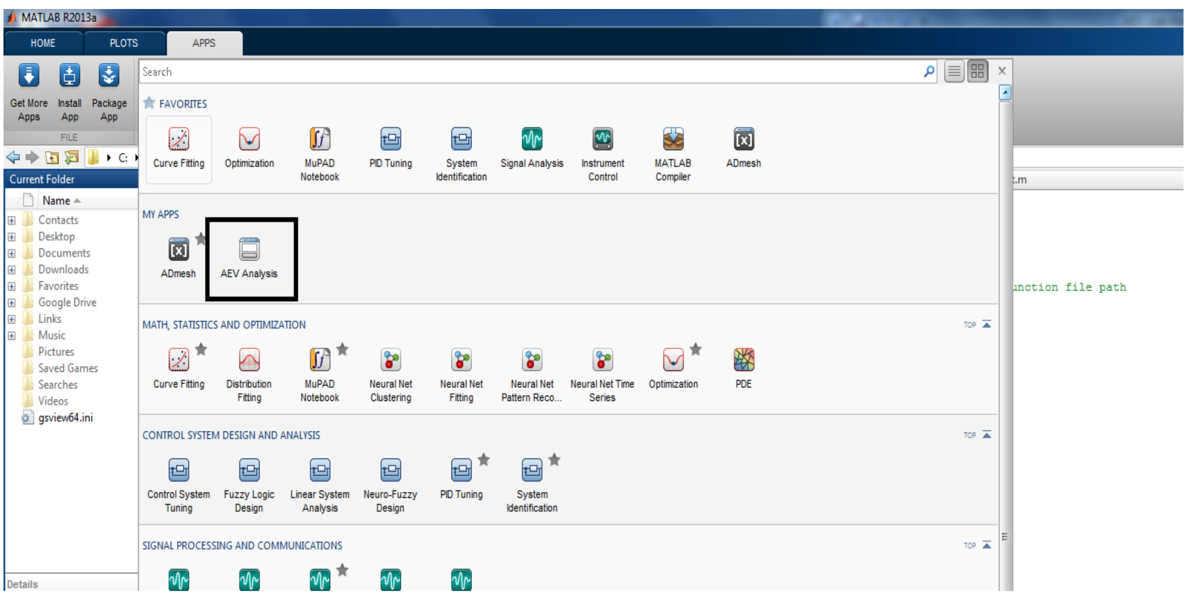


Figure 36: MATLAB Apps

Simply click on the “AEV Analysis” App and the software window will open. See Figure 37.

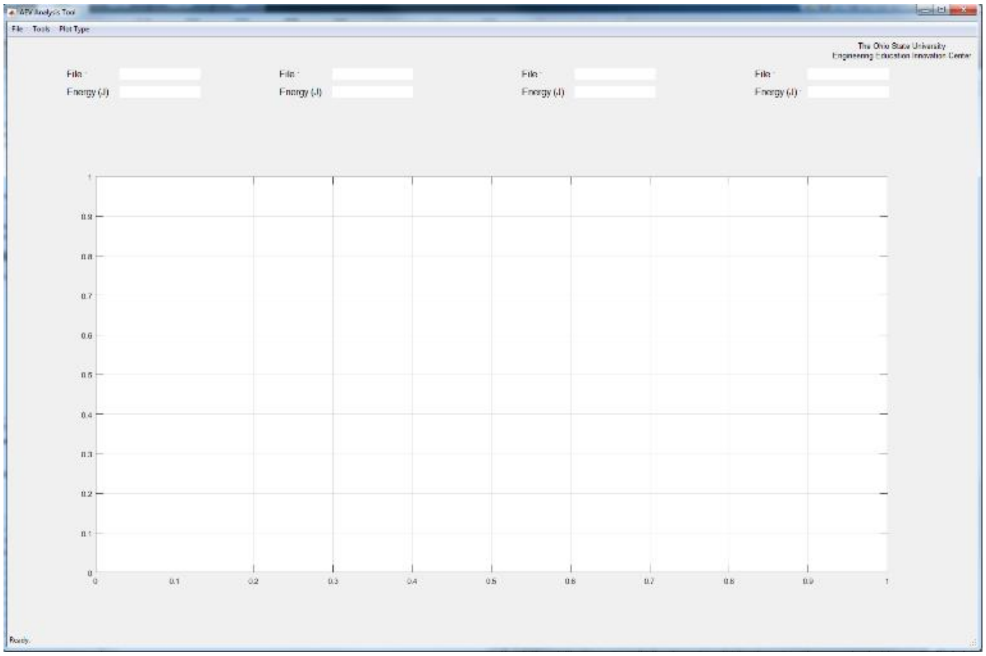


Figure 37: AEV Analysis Software

The AEV Analysis tool has a File, Tools and Plot Type menu at the top left hand corner of the figure window. Below is a brief description of these options

1. File
   a. **Open EEProm File… (.mat):** Opens, loads, and analyzes a MATLAB data file containing EEPROM data recorded by the Arduino motor controller. (Details discussed in "System Analysis 2 - Performance Analysis").
   b. **Clear File:** Allows a user to remove a file loaded in the GUI.
2. Tools
   a. **Download Arduino Data:** Downloads EEPROM data from the Arduino motor controller following an AEV track run and saves the data as a (.mat) file. (Details discussed in "Downloading Arduino Data").
   b. **Export Figure:** Allows the user to export plots displayed in the app for documentation and presentation.
   c. **View Performance Analysis:** Opens up the data set in a MATLAB table so the user can view the raw and calculated data.
   d. **View Arduino Program:** Allows the user to see an appended Arduino code (if copied and pasted). The user can then use this as a reference if needed to revert back to what Arduino code was used to create the data set.
   e. Append Arduino Program: Allows the user to copy and paste an Arduino code to a data set for they can look back at the code at a later time.

3. Plot Type
    a. Power vs. Time: Sets the x-axis of the plot to time (seconds).
    b. Power vs Distance: Sets the x-axis of the plot to distance (meters).

Downloading Arduino Data

The AEV Analysis tool communicates with Arduino using a serial port (COM #). In the Arduino IDE, the COM port needs to be specified for loading a program onto the Arduino motor controller. The AEV Analysis tool automatically detects which com port the AEV is connected to so there is no need to take this step anymore. The following steps will describe how to download Arduino data.

1. Connect the AEV to a PC using the provided USB cord.
2. On the Arduino motor controller you will see a yellow light flashing, wait until the yellow light becomes solid.
3. Under Tools, select "Download Arduino Data". You should see the yellow and green light on the Arduino board turn solid. The progress bar at the bottom left hand side of the figure window should display the progress of the download.
4. When the EEPROM data has been downloaded successfully, a prompt will display asking the user if they would like to store the Arduino code used for the run.
5. The next prompt that will display is for saving the EEPROM data into a (.mat) file (make sure to save in a location you know where to find the data set and save the data set with a unique save name so you can go back if needed. Also, do not have a save name with numbers, else MATLAB will return with an error.)
6. The download is now complete. The (.mat) file can now be used for viewing performance analyses following a propulsion efficiency analysis.

Performance Analysis

Knowing how the vehicle is performing is crucial to meeting the operational objectives for the project. In System Analysis 1 and 2, taught how to calculate performance characteristics of the AEV through experimental research. The project is now entering into the cycle consisting of

1. Analyzing data
2. Making design decisions from the analyzed data
3. Researching design decisions
4. Testing and comparing to previous designs

This cycle will then continue until the final design is reached. The AEV Analysis tool is designed to provide an in-depth analysis of the AEV performance to aid in design decisions. This step would typically be followed by the "Downloading Arduino Data" section of this document. For a first time user, a MATLAB file named "Test_Data.mat" should be provided with this tool in the folder “EEProm Data”. If the intent is to analyze data from an AEV run, first refer to the “Downloading Arduino Data” and then follow the following steps:

1. Under File, select “Open EEProm File (.mat)…” and select a (.mat) file.
2. The tool will load the EEPROM data stored from an AEV run and perform an analysis similar to System Analysis 2 and plot the results. The color of the filename corresponds to the line color on the plot. The user should see the file name and total energy appear in one of the file boxes.

Two plot options are available under the “Plot Type…” toolbar menu. Power vs. Time (s) and Power vs. Distance (m). Selecting either of these will automatically change the x-axis of the plot.

For documentation and presentation purposes, the tool allows you to export the figures you see in the program. Under Tools, select “Export Figure”. The figure that is exported can be saved as different file types such as JPEG or PNG. When saving the file, just change the “Save as type:”.

Do not forget to start on the draft of the oral presentation. See Lab 12: Oral Presentation for details.

Executive Summary

(Due Lab 08B: Performance Test 1)

**** THIS EXECUTIVE SUMMARY IS TO BE DONE INDIVIDUALLY ****

For details on content and formatting, see the Technical Communications Guide on Executive Summary specifications. In addition to requirements listed in the Technical Communications Guide, be sure to briefly address the following questions. Answer within your summary, not with numbers or bullets.

- Provide the following figures and tables:
  - A plot of Energy Analysis vs. Time
  - A plot of Energy Analysis vs. Distance

  Note: Use the "Export Figure" (see Lab Activity for this feature). Do NOT use Snipping Tool or ALT/CTRL + Print Screen. These features make the figure distorted and not professional. "Export Figure" is to make the figure nice and clean.

- Provide an explanation for the figures and tables and what they are representing (Hint: refer to the Arduino Code appended to the data).

- (QUESTION 1): Come together as a team to discuss what responsibilities needed to complete the AEV project? Create the team's schedule (that can be used in the PDR) and the tasks that need to be completed with the team member(s) responsible. In the executive summary (that is individual) discuss YOUR role in the team and what tasks are YOUR responsibility(ies).

Do not forget to start on the draft of the oral presentation. See Lab 12: Oral Presentation for details (TEAM ASSIGNMENT).

Grading Rubric – Lab 07 Design Analysis Tool

Instructor:____________________ GTA:____________________ Group:_____

Content

Executive Summary Content	Purpose		Background		Total
	3	Good / restated	3	Complete	
	1	Poor / copied	1	Incomplete / not specific	
	0	Lacking	0	Missing	__ 6
	Figure and Tables		**Question 1 (Preliminary Code)**		
	6	All 5, properly labeled, explained	3	Justified with data and theory	
	3	Missing 1 / not fully explained	2	Justified, incomplete data or theory	
	1	Not fully reasoned / missing 2+	1	Not fully reasoned / verified	
	0	Missing	0	Missing	___ 9
	Conclusions				
	5	Relevant & supported			
	3	Unsupported / irrelevant			
	2	Very lacking			
	0	Missing			___ 5

Content Total / 20

Format & Language

Total

Content	Content	
	4	Appropriate content
	2	Excess content / vague details
	0	Vast excess content / content very vague

__ 4

Labels & References	Labels		Referencing	
	3	All present with good label descriptions	3	Well referenced & described in body
	2	Some missing or poor descriptions	2	Poor descriptions and/or references
	0	Missing or no description	0	Missing references

__ 6

General Format	Errors	
	4	Fewer than 2 mistakes
	2	2-5 mistakes
	0	More than 5 mistakes

__ 4

Structure	Brevity		Clarity		Flow	
	4	Concise	3	Clear	4	Smooth
	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed

__ 11

Wording	Professionalism		Tense / Person	
	3	No slang, jargon, etc.	3	No slips in tense/person
	2	Some slips in professionalism	2	1-3 slips in tense/person
	1	Distracting / poor	1	4-8 slips in tense/person
	0	Exceedingly poor	0	More than 8 errors

__ 6

General	Spelling / Grammar / Punctuation	
	4	Minor errors
	3	Few errors, but not distracting
	1	Distracts from readability
	0	Complete lack of proofreading

__ 4

Writing Total / 35

Content Total / 20

Exec. Sum. Total / 55

Instructor/ GTA End-of-Lab Signoff

Lab 8: ______________________________

Lab 08: Performance Test 1 – Design

Background

From this week forward, labs are meeting three times a week with each week having a small objective for the team to complete. It is up to team to determine how to break up the tasks needed to complete the objective (should be indicated in the team's project schedule).

The beginning of each week a **TRR** or **Test Readiness Review**. A TRR "assesses test objectives, test methods and procedures, scope of tests, and safety and confirms that required test resources have been properly identified and coordinated to support planned tests. The TRR verifies the traceability of planned tests to program requirements and user needs. The TRR determines the completeness of test procedures and their compliance with test plans and descriptions" (ref. geekinterview.com).

A **PDR** or **Preliminary Design Review** is the mid-term report that establishes the baseline and underlying architecture to ensure that the system under review (in this case the AEV) has a reasonable expectation of satisfying the requirements within the allocated schedule. It typically gets reviewed by a program manager to verify and understand if there are any major design issues, roadblocks, or schedule conflicts. The PDR should address and resolve any critical issues.

A **CDR** or **Critical Design Review** is the final report demonstrating the maturity of the project or design (of a final AEV) before full-scale fabrication, assembly or integration. The CDR provides the schedule of events and how everything was completed as established in the PDR.

These technical reviews and reports have been adopted from industry and the military. Such companies who use them include; NASA, Boeing, Space-X, and Tesla, amongst others.

Layout for the Performance Tests:

Performance Test	Objective	Description
1	Design	Design two different AEV's and test accordingly to determine which AEV design would start to complete the MCR and minimized the energy used.
2	Code	Develop two Arduino codes to complete the full track layout as stated in the MCR. These two Arduino codes can be used to determine which one performs consistently and minimizes the energy used.
3	Energy	Complete the full scenario as stated in the MCR in which would provide the most energy efficient, consistent vehicle.
4	Final Testing	Tie any lose ends up and run the final test which will go into the CDR.

Note: if the team is unable to complete the task(s) or objectives laid out, provide reasons why the team was unable to finish. Do not provide excuses why the team was unable to finish!

<u>Good Reason (for Performance Test 2):</u>
"The team was only able to complete half the track/mission instead of the full track layout with two different Arduino Codes. The team did not plan accordingly and ran out of time due to this reason. The team will look ahead so all tasks will be completed in Performance Test 3, as well as, tie up any lose ends from Performance Test 2. The team has included a schedule of tasks for these lose ends that will be completed in the next Performance Test."
(*Reasons of failure with fixes for the problem*)

<u>Bad Reason/Excuse (for Performance Test 2):</u>
"The team was only able to complete half the track/mission instead of the full track layout with two different Arduino Codes. The team found out that the track is extremely inconsistent and the instructor kept providing bad batteries."
(*Bad excuses with no solutions to problem*)

An example of a schedule of tasks is seen in the Technical Communication Guide and below. The schedule does NOT have to look like below but needs to be informative. Provide the teammate's names in the "Teammate" spots.

Table 5: Example Schedule

	No.	Task	Start	Finish	Due Date	Teammate 1	Teammate 2	Teammate 3	Teammate 4	% Complete
Performance Test 1	1	Wind Tunnel	8 - June	8 - June	12 - June	x	x	x	X	100
	2	AEV 1 Construction	8 - June	12 - June	12 - June	x	x			100
	3	AEV 1 Testing	8 - June	12 - June	12 - June			x	x	50
	4	AEV 2 Construction	10 - June	12 - June	12 - June	x	x			100
	5	AEV 2 Testing	10 - June	12 - June	12 - June			x	x	50
	6	Weekly Report	8 - June	12 - June	12 - June	x	x	x		100
	7	SolidWorks Model	8 - June	15 - June	17 - June				x	100

Executive Summary – Test Readiness Review

(Due Lab 08 A: Performance Test 1 Lab)

For details on content and formatting, see the Technical Communications Guide on Executive Summary specifications. In addition to requirements listed in the Technical Communications Guide, be sure to briefly address the following questions. Answer within your summary, not with numbers or bullets.

- (PURPOSE) Clearly define the purpose/objective for the lab this week. Address the overall goals, objectives and briefly explain how the team will complete the tasks.

- (TASK/TEAM MEMBER) Discuss the necessary tasks that need to be completed and how the team is going to distribute the work evenly amongst all team members.

- (TWO CONCEPTS) Discuss the two concepts the team is going to be testing this week and why they were chosen.

Note: this should be a small executive summary discussing how the team is going to distribute the work for the next week. No more than a page is required.

Grading Rubric – Lab 08 Performance Test 1 TRR

Instructor:____________________ GTA:____________________ Group:_____

Content

Executive Summary Content	Purpose		Background		Total
	3	Good / restated	3	Complete	
	1	Poor / copied	1	Incomplete / not specific	
	0	Lacking	0	Missing	__ 6
	Task/Team Member		**Two Concepts**		
	6	Lists tasks and team member involved	3	Describes two concepts (Not the Sample AEV)	
	4	Lists tasks but forgets to lists team member involvement	2	Only one concept discussed	
	2	Poor	1	Not fully discussed concept, briefly mentioned	
	0	Missing	0	Missing	__ 9
	Conclusions				
	5	Relevant & supported			
	3	Unsupported / irrelevant			
	2	Very lacking			
	0	Missing			__ 5

Content Total / 20

Format & Language

Total

Content	Content		
	4	Appropriate content	
	2	Excess content / vague details	
	0	Vast excess content / content very vague	__ 4

Labels & References	Labels		Referencing		
	3	All present with good label descriptions	3	Well referenced & described in body	
	2	Some missing or poor descriptions	2	Poor descriptions and/or references	
	0	Missing or no description	0	Missing references	__ 6

General Format	Errors		
	4	Fewer than 2 mistakes	
	2	2-5 mistakes	
	0	More than 5 mistakes	__ 4

Structure	Brevity		Clarity		Flow		
	4	Concise	3	Clear	4	Smooth	
	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts	
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts	
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed	__ 11

Wording	Professionalism		Tense / Person		
	3	No slang, jargon, etc.	3	No slips in tense/person	
	2	Some slips in professionalism	2	1-3 slips in tense/person	
	1	Distracting / poor	1	4-8 slips in tense/person	
	0	Exceedingly poor	0	More than 8 errors	__ 6

General	Spelling / Grammar / Punctuation		
	4	Minor errors	
	3	Few errors, but not distracting	
	1	Distracts from readability	
	0	Complete lack of proofreading	__ 4

Writing Total	/ 35
Content Total	/ 20
Exec. Sum. Total	/ 55

Instructor/ GTA End-of-Lab Signoff

Lab 8
TRR: ______________________________________

Preliminary Design Review (PDR) Report

(Due Lab 09B: Performance Test 2 Lab)

Write a Lab Report

For details on content and formatting, see the Technical Communications Guide on Lab Report specifications.

Executive Summary

- Clearly define the purpose of the lab. Address the overall goals, objectives and briefly explain what you did to complete the tasks.
- Discuss in depth the need for an Advance Energy Vehicle (AEV) and how the AEV will be used to meet the objectives and requirements as stated in the Mission Concept Review (MCR).

Results

- (DESCRIPTION OF TWO CONCEPTS) Provide a brief description of the group's two prototype AEV concepts used in Performance Test 1 (include a figure of each concept in the report). How did the four designs the team came up in Lab 01: Creative Design Thinking evolved to the two prototype concepts used in Performance Test 1?
- (SCREENING AND SCORING MATRICES) Provide a screening and scoring matrices (Lab 03: Concept Screening and Scoring) to help defend prototype designs to the four concepts from Lab 3 and Sample AEV.
- (OBSERVATIONS FROM RUN) Address the observations the group made while comparing the two concepts. (How did the two designs behave differently with the same control program? Was there a significant difference in the total energy consumed by each design? Was that what the group was expecting?)
- How did this Performance Test affect the team's design process? How can the knowledge gained from the System Analysis Tests 1-2 enhance our understanding in the AEV's performance?
- Incorporate the following figures into the discussion (from both AEV prototype concepts):
    - *System Efficiency vs. Advance Ratio* from wind tunnel testing similar to the one constructed in System Analysis 1 to help aid in the team's decision in the propeller used
    - Figure of supplied power vs time/distance (team can pick either to plot vs. time or vs. distance).
    - *Table that has a breakdown of Supplied Energy* for each line of code of the AEV's operation (each phase of the vehicle's motion that consumes energy)

** Make sure to include a brief discuss of the figures and tables. Verify that the figures and tables are labeled correctly with appropriate units, title, and x- and y-axis labels **

Conclusion and Recommendations

- Develop a thoughtful yet concise conclusion from the results obtained in the lab.
- Select a design with which the group will proceed and defend the group's selection with experimental results.
- (REASONS FOR INCOMPLETENESS / RESOLVING ERROR / RECOMMENDATIONS) Provide any recommendations for future lab analysis and/or reasons for incompleteness of the performance test.

Appendix

- (SCHEDULE) Provide the group's project schedule with the tasks that need to be completed, start and end dates, due dates, the group members percent completed, their roles for tasks that need to be completed, and the percentage completed (See Technical Communications Guide for example).
- (SOLIDWORKS) Provide the SolidWorks model of the two prototype designs and ensure that the figure has the 3 primary orthographic views with overall dimensions, estimated weight, estimated cost, and bill of materials.

Grading Rubric – Preliminary Design Review (PDR)

Instructor:____________________ GTA:____________________ Group:_____

Content

Total

Abstract	Purpose		Results		Recommendation		Total
	3	Purpose Identified	4	Clear & concise	3	Direct & justified	
	2	Purpose not clear	2	Wordy and/or unclear	2	Unclear and/or weak	___
	0	Poor / missing	0	Poor / missing	0	Poor / missing	10

Introduction	Purpose		Background		Total
	4	Good / restated	4	Complete	
	2	Poor / copied	2	Incomplete / not specific	__
	0	Missing	0	Missing	8

Experimental Methodology	Procedure		Equipment		Total
	3	Could replicate experiment	3	Thorough description w/ pictures or diagram of setup	
	2	Some details missing	2	Setup unclear or equipment left out	
	1	Missing several important steps	1	Missing pictures/diagrams	___
	0	Exceedingly poor	0	Exceedingly poor	6

Results	Objectivity		Observations		Data Placement		Total
	2	Objective results	2	Objective observations	4	Easy to find	
	1	Some subjectivity	1	Some subjectivity	2	Some difficulty	__
	0	Mostly subjective	0	Missing	0	Mostly hidden	8

Results	Data Analysis		Figures & Tables		Total
	4	Logical steps / thoroughly explained	16	Good use of tables and figures	
	2	Difficult to follow or missing critical steps (i.e. sample calculations)	8	Needs more/fewer tables/figures	__
	0	Exceedingly poor	0	Exceedingly poor	20

Discussion	Analysis		Potential Error		
	4	Clear trends identified & relate to purpose	3	Reasonable / well justified	
	2	Trends unrelated to purpose / some missing	2	Unreasonable / poorly justified	
	0	Exceedingly poor / missing	0	Exceedingly poor / missing	__ 7
	Comparison to Theory		**Description of Two Prototypes**		
	4	Quantitative and logical	5	Justified w/ data & theory of matrices	
	3	Qualitative or illogical	3	Justified w/o data or theory of matrices	
	2	Poor / Lacking critical details	2	Not fully reasoned / verified	
	0	Exceedingly poor / missing	0	Exceedingly poor / missing	__ 9
	Screen AND Scoring Matrices		**Observations from Run**		
	3	Justified w/ data & theory	3	Justified w/ data & theory	
	2	Justified w/o data or theory	2	Justified w/o data or theory	
	1	Not fully reasoned / verified	1	Not fully reasoned / verified	
	0	Exceedingly poor / missing	0	Exceedingly poor / missing	__ 6

Conclusion & Recommendations	Summary		Conclusions		Resolving Error		
	7	Summarized experiment, results, & discussion	7	Supported by data & relevant to purpose	6	Addresses error / reasonable	
	5	Summary lacking in parts or missing critical part	5	No link to results / discussion	4	Unaddressed or unreasonable	
	3	Poor / missing two parts	3	Lacking critical thinking	2	Poor / Lacking thought	
	0	Exceedingly poor / missing	0	Very poor / missing	0	Missing	__ 20
	Recommendations		**Reasons for Incompleteness**		**Format & Language**		
	7	Well thought out / reasoned	7	Justified w/ data, theory, & suitable references	6	< 2 mistakes in format < 2 mistakes in language	
	5	Not fully reasoned	5	Justified w/o data or theory or references	3	4-6 mistakes in total	
	3	Very poor	3	Not reasoned / verified	0	> 6 mistakes	
	0	Missing	0	Very poor / missing			__ 20

Appendix	Schedule		SolidWorks Models		
	18	Has completed/start/end dates, group members, percentage completed, roles, tasks, and percentage completed. Formatted Correctly	18	Has **both** prototypes with bill of materials, overall dimensions, weight, cost and 3 views	
	12	Lacking a few of components from above	12	Lacking a few of components from above	
	9	Has very basic information, formatting issues	9	Missing prototype / has very basic information	
	5	Lacking or exceedingly poor	5	Exceedingly poor	___
	0	Missing	0	Missing / Hand drawn	36

Format & Language

Total

Content Placement	Body Content		Appendix Content		
	4	All in correct sections	4	Appropriately placed	
	2	Minor misplaced content	2	Minor misplaced content	___
	0	Large sections of misplaced content	0	Too much content in appendix	8

Labels & References	Labels & Placement		Referencing		
	4	All present w/descriptions & placement	4	Well referenced & described in body	
	2	Some missing or poor descriptions	2	Poor descriptions and/or references	___
	0	Missing or no description	0	Missing references	8

General Format	Errors		Citations		
	4	Fewer than 2 mistakes	3	Proper citations	
	2	2-5 mistakes	2	Few citation mistakes	___
	0	More than 5 mistakes	0	Poor / missing citations	7

Structure1	Brevity		Clarity		Flow		
	4	Concise	4	Clear	4	Smooth	
	3	Some wordy areas	3	Few parts confusing	3	Few disjointed parts	
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts	___
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed	12

Wording	Professionalism		Tense / Person		
	5	No slang, jargon, etc.	5	No slips in tense/person	
	4	Some slips in professionalism	4	1-3 slips in tense/person	
	2	Distracting / poor	2	4-8 slips in tense/person	___
	0	Exceedingly poor	0	More than 8 errors	10

	Spelling / Grammar / Punctuation		
General	5	Minor errors	
	3	Few errors, but not distracting	
	1	Distracts from readability	
	0	Complete lack of proofreading	__ 5

Writing Total	/ 50
Content Total	/ 150
Total	/ 200

Lab 09: Performance Test 2 – Code

Executive Summary – Test Readiness Review

(Due Lab 9A: Performance Test 2 Lab)

Write an Executive Summary

For details on content and formatting, see the Technical Communications Guide on Executive Summary specifications.

Lab Specific Directions

- In addition to requirements listed in the Technical Communications Guide, be sure to briefly address the following questions. Answer within your summary, not with numbers or bullets.
    - (PURPOSE) Clearly define the purpose/objective for the lab this week. Address the overall goals, objectives and briefly explain how the team will complete the tasks.

    - (TASK/TEAM MEMBER) Discuss the necessary tasks that need to be completed and how the team is going to distribute the work evenly amongst all team members.

    - (TABLE OF BREAKDOWN DISTANCES) Discuss how the team will complete one full circuit as stated in the Mission Concept Review (MCR). It may be a good to provide a table with the breakdown of the distances that AEV needs to travel and the wait times.

Grading Rubric – Lab 09: Performance Test 2

Instructor:____________________ GTA:____________________ Group:_____

Content

Executive Summary Content	Purpose		Background		Total
	3	Good / restated	3	Complete	
	1	Poor / copied	1	Incomplete / not specific	
	0	Lacking	0	Missing	___ 6
	Task of Team Members		**Table of Breakdown Distances**		
	6	Lists tasks and team member involved	3	Table includes all distances and times	
	4	Lists tasks but forgets to lists team member involvement	2	Table is missing scenario sections	
	2	Poor	1	Poor	
	0	Missing	0	Missing	___ 9
	Conclusions				
	5	Relevant & supported			
	3	Unsupported / irrelevant			
	2	Very lacking			
	0	Missing			___ 5

Content Total / 20

Format & Language

Total

Content	Content	
	4	Appropriate content
	2	Excess content / vague details
	0	Vast excess content / content very vague

__ / 4

Labels & References	Labels		Referencing	
	3	All present with good label descriptions	3	Well referenced & described in body
	2	Some missing or poor descriptions	2	Poor descriptions and/or references
	0	Missing or no description	0	Missing references

__ / 6

General Format	Errors	
	4	Fewer than 2 mistakes
	2	2-5 mistakes
	0	More than 5 mistakes

__ / 4

Structure	Brevity		Clarity		Flow	
	4	Concise	3	Clear	4	Smooth
	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed

__ / 11

Wording	Professionalism		Tense / Person	
	3	No slang, jargon, etc.	3	No slips in tense/person
	2	Some slips in professionalism	2	1-3 slips in tense/person
	1	Distracting / poor	1	4-8 slips in tense/person
	0	Exceedingly poor	0	More than 8 errors

__ / 6

General	Spelling / Grammar / Punctuation	
	4	Minor errors
	3	Few errors, but not distracting
	1	Distracts from readability
	0	Complete lack of proofreading

__ / 4

Writing Total / 35

Content Total / 20

Exec. Sum. Total / 55

Instructor/ GTA End-of-Lab Signoff

Lab 10

TRR: ____

Lab Memo

(Due Lab 10B: Performance Test 2 Lab)

Write a Lab Memo

For details on content and formatting, see the Technical Communications Guide on Lab Memo specifications.

Results & Discussion

- (PROGRAMMING STRATEGY) Discuss the team's programming strategy during testing and the need for necessary changes to the AEV so that it will complete the objectives as stated in the Mission Concept Review (MCR).

- (OBSERVATIONS) Discuss any observations made during the runs (i.e. AEV physical characteristics on the track, speed, balance between program changes, energy and efficiency results, etc.).

- (TABLE/FIGURE) Provide a figure of power versus distance or time for the track testing with the energy table (similar to one to the one from Lab 06: System Analysis 2 – Performance Data Analysis lab).

Conclusion and Recommendations

- Develop a thoughtful yet concise conclusion from the results obtained in the lab and provide any recommendations for future lab analysis.

Grading Rubric – Lab 09: Performance Test 2

Instructor:____________________ GTA:____________________ Group:_____

Content

Section	Purpose		Background				Total
Introduction	4	Good / restated	4	Complete			
	2	Poor / copied	2	Incomplete / not specific			
	0	Missing	0	Missing			__ 8

Section	Objectivity		Data Placement		Data Analysis		Total
Results & Discussion	2	Objective results	3	Easy to find	4	Logical steps / thoroughly explained	
	1	Some subjectivity	2	Some difficulty	2	Difficult to follow or missing critical steps (sample calcs)	
	0	Mostly subjective	0	Mostly hidden	0	Exceedingly poor	__ 9
	Figures & Tables		**Comparison to Theory**		**Potential Error**		
	3	Good use of tables and figures	3	Quantitative and logical	3	Reasonable / well justified	
	2	Needs more/fewer tables/figures	1	Qualitative or illogical	1	Unreasonable / poorly justified	
	0	Exceedingly poor	0	Missing	0	Exceedingly poor / missing	__ 9
	Analysis		**Programming Strategy**		**Observations**		
	4	Clear trends identified & relate to purpose	5	Supported by data & relevant to purpose	5	Supported by data & relevant to purpose	
	2	Trends unrelated to purpose / some missing	2	No link to observations / discussion	2	No link to observations / discussion	
	0	Exceedingly poor / missing	1	Lacking critical thinking	1	Lacking critical thinking	
			0	Missing	0	Missing	__ 14

Section	Summary		Conclusions		Resolving Error		Total
Conclusion & Recommendations	4	Summarized experiment, results, & discussion	5	Supported by data & relevant to purpose	4	Addresses error / reasonable	
	3	Summary lacking in parts or missing critical part	3	No link to results / discussion	3	Unaddressed or unreasonable	
	1	Poor / missing parts	2	Lacking critical thinking	2	Poor / Lacking thought	
	0	Very Poor / Missing	0	Very poor / missing	0	Missing	__ 13
	Recommendations		**Table / Figure**		**Format & Language**		
	4	Well thought out / reasoned	4	Labeled, phases, explained, reasonable	4	< 2 mistakes in format < 2 mistakes in language	
	3	Not fully reasoned	3	Not fully defined	2	4-6 mistakes in total	
	2	Very poor	2	Lacking parts	0	> 6 mistakes	
	0	Missing	0	Missing			__ 12

Format & Language

Total

Content Placement	Body Content		Appendix Content		
	3	All in correct sections	3	Appropriately placed	
	2	Minor misplaced content	2	Minor misplaced content	__
	0	Large sections of misplaced content	0	Too much content in appendix	6

Labels & References	Labels & Placement		Referencing		
	3	All present w/descriptions & placement	3	Well referenced & described in body	
	2	Some missing or poor descriptions	2	Poor descriptions and/or references	__
	0	Missing or no description	0	Missing references	6

General Format	Errors		
	4	Fewer than 2 mistakes	
	2	2-5 mistakes	__
	0	More than 5 mistakes	4

Structure	Brevity		Clarity		Flow		
	3	Concise	3	Clear	3	Smooth	
	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts	
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts	___
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed	9

Wording	Professionalism		Tense / Person		
	3	No slang, jargon, etc.	3	No slips in tense/person	
	2	Some slips in professionalism	2	1-3 slips in tense/person	
	1	Distracting / poor	1	4-8 slips in tense/person	___
	0	Exceedingly poor	0	More than 8 errors	6

General	Spelling / Grammar / Punctuation		
	4	Minor errors	
	3	Few errors, but not distracting	
	1	Distracts from readability	__
	0	Complete lack of proofreading	4

Writing Total / 35

Content Total / 65

Memo Total / 100

Instructor/ GTA End-of-Lab Signoff

Lab 10 ______________________________________

Lab 10: Performance Test 3 – Energy Optimization

Executive Summary - Test Readiness Review

(Due Lab 10A: Performance Test 3 Lab)

Write an Executive Summary

For details on content and formatting, see the Technical Communications Guide on Executive Summary specifications. In addition to requirements listed in the Technical Communications Guide, be sure to briefly address the following questions. Answer within your summary, not with numbers or bullets.

- (PURPOSE) Clearly define the purpose/objective for the lab this week. Address the overall goals, objectives and briefly explain how the team will complete the tasks.

- (TASK/TEAM MEMBER) Discuss the necessary tasks that need to be completed and how the team is going to distribute the work evenly amongst all team members.

- (DISCUSSION OF ENERGY OPTIMIZATION) Discuss how the team will complete the objective as stated in the Mission Concept Review (MCR) while having the most efficient and cost effective vehicle. What tasks will need to be completed to obtain these results?

Grading Rubric – Lab 10 Performance Test 3

Instructor:____________________ GTA:____________________ Group:_____

Content

Executive Summary Content	Purpose		Background		Total
	3	Good / restated	3	Complete	
	1	Poor / copied	1	Incomplete / not specific	
	0	Lacking	0	Missing	__ / 6
	Task of Team Members		**Discussion of Energy Optimization**		
	4	Lists tasks and team member involved	3	Discussed on creating an efficient and cost effective vehicle	
	2	Lists tasks but forgets to lists team member involvement	2	Discussed only one of the two options	
	1	Poor	1	Poor	
	0	Missing	0	Missing	___ / 9
	Conclusions				
	5	Relevant & supported			
	3	Unsupported / irrelevant			
	2	Very lacking			
	0	Missing			___ / 5

Content Total / 20

Format & Language

Total

Content	Content	
	4	Appropriate content
	2	Excess content / vague details
	0	Vast excess content / content very vague

__ 4

Labels & References	Labels		Referencing	
	3	All present with good label descriptions	3	Well referenced & described in body
	2	Some missing or poor descriptions	2	Poor descriptions and/or references
	0	Missing or no description	0	Missing references

__ 6

General Format	Errors	
	4	Fewer than 2 mistakes
	2	2-5 mistakes
	0	More than 5 mistakes

__ 4

Structure	Brevity		Clarity		Flow	
	4	Concise	3	Clear	4	Smooth
	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed

__ 11

Wording	Professionalism		Tense / Person	
	3	No slang, jargon, etc.	3	No slips in tense/person
	2	Some slips in professionalism	2	1-3 slips in tense/person
	1	Distracting / poor	1	4-8 slips in tense/person
	0	Exceedingly poor	0	More than 8 errors

__ 6

General	Spelling / Grammar / Punctuation	
	4	Minor errors
	3	Few errors, but not distracting
	1	Distracts from readability
	0	Complete lack of proofreading

__ 4

Writing Total / 35

Content Total / 20

Exec. Sum. Total / 55

Instructor/ GTA End-of-Lab Signoff

Lab 11

TRR: ____

Lab Memo – Lab 10: Performance Test 3

(Due Lab 11B: Performance Test 4 Lab)

Write a Lab Memo

For details on content and formatting, see the Technical Communications guide on Lab Memo specifications.

Results & Discussion

- (STRATEGY) Discuss the team's programming strategy during testing and the need for necessary changes to the AEV so that it will complete the objectives as stated in the Mission Concept Review (MCR).

- (OBSERVATIONS) Discuss any observations made during the runs (i.e. AEV physical characteristics on the track, speed, balance between program changes, energy and efficiency results, etc.).

- (TABLE / FIGURE) Provide a figure of power and efficiency versus distance or time for the track testing with the energy table (similar to one to the one from System Analysis 1 and 2 labs).

- Discuss what tasks were needed to be completed to obtain the most efficient vehicle the team created.

Conclusion and Recommendations

- Develop a thoughtful yet concise conclusion from the results obtained in the lab and provide any recommendations for future lab analysis before the final test next week.

Grading Rubric – Lab 10: Performance Test 3

Instructor:____________________ GTA:____________________ Group:______

Content

Introduction	Purpose		Background		Total
	4	Good / restated	4	Complete	
	2	Poor / copied	2	Incomplete / not specific	
	0	Missing	0	Missing	__ 8

Results & Discussion	Objectivity		Data Placement		Data Analysis		Total
	2	Objective results	3	Easy to find	4	Logical steps / thoroughly explained	
	1	Some subjectivity	2	Some difficulty	2	Difficult to follow or missing critical steps (sample calcs)	
	0	Mostly subjective	0	Mostly hidden	0	Exceedingly poor	__ 9
	Tables & Figures		**Comparison to Theory**		**Potential Error**		
	3	Good use of tables and figures	3	Quantitative and logical	3	Reasonable / well justified	
	2	Needs more/fewer tables/figures	1	Qualitative or illogical	1	Unreasonable / poorly justified	
	0	Exceedingly poor	0	Missing	0	Exceedingly poor / missing	__ 9
	Analysis		**Efficient Vehicle**		**Strategy / Observations**		
	4	Clear trends identified & relate to purpose	5	Supported by data & relevant to purpose	5	Supported by data & relevant to purpose	
	2	Trends unrelated to purpose / some missing	2	No link to observations / discussion	2	No link to observations / discussion	
	0	Exceedingly poor / missing	1	Lacking critical thinking	1	Lacking critical thinking	
			0	Missing	0	Missing	__ 14

Conclusion & Recommendations	Summary		Conclusions		Resolving Error		Total
	4	Summarized experiment, results, & discussion	5	Supported by data & relevant to purpose	4	Addresses error / reasonable	
	3	Summary lacking in parts or missing critical part	3	No link to results / discussion	3	Unaddressed or unreasonable	
	1	Poor / missing parts	2	Lacking critical thinking	2	Poor / Lacking thought	
	0	Very Poor / Missing	0	Very poor / missing	0	Missing	__ 13
	Recommendations		**Table / Figure**		**Format & Language**		
	4	Well thought out / reasoned	4	Labeled, phases, explained, reasonable	4	< 2 mistakes in format < 2 mistakes in language	
	3	Not fully reasoned	3	Not fully defined	2	4-6 mistakes in total	
	2	Very poor	2	Lacking parts	0	> 6 mistakes	
	0	Missing	0	Missing			__ 12

Format & Language

	Body Content		Appendix Content		Total
Content Placement	3	All in correct sections	3	Appropriately placed	
	2	Minor misplaced content	2	Minor misplaced content	
	0	Large sections of misplaced content	0	Too much content in appendix	__ 6

	Labels & Placement		Referencing		
Labels & References	3	All present w/descriptions & placement	3	Well referenced & described in body	
	2	Some missing or poor descriptions	2	Poor descriptions and/or references	
	0	Missing or no description	0	Missing references	__ 6

	Errors		
General Format	4	Fewer than 2 mistakes	
	2	2-5 mistakes	
	0	More than 5 mistakes	__ 4

	Brevity		Clarity		Flow		
Structure	3	Concise	3	Clear	3	Smooth	
	2	Some wordy areas	2	Few parts confusing	2	Few disjointed parts	
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts	
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed	___ 9

	Professionalism		Tense / Person		
Wording	3	No slang, jargon, etc.	3	No slips in tense/person	
	2	Some slips in professionalism	2	1-3 slips in tense/person	
	1	Distracting / poor	1	4-8 slips in tense/person	
	0	Exceedingly poor	0	More than 8 errors	___ 6

	Spelling / Grammar / Punctuation		
General	4	Minor errors	
	3	Few errors, but not distracting	
	1	Distracts from readability	
	0	Complete lack of proofreading	__ 4

Writing Total / 35

Content Total / 65

Memo Total / 100

Instructor/ GTA End-of-Lab Signoff

Lab 11 ____

Lab 11: Performance Test 4 – Final Testing

Guidelines for AEV Final Test Evaluation

1. There will be two runs allowed per team and the better of the two runs will be the score awarded.

2. The tests can be run at any time during Performance Test 4 (PT4). Both runs don't have to be on the same day.

3. What if a vehicle does not travel far enough to trigger the gate, or does not travel far enough to engage the cargo?

   Students will be allowed to be stationed at the gate and the cargo area and the students may

   i. move the vehicle with their hands
   ii. or manually open the gate

If this occurs the loss of points will occur (points will not be awarded for the step but any steps after can be awarded).

4. If the vehicle crashes into the cargo rather than gently engaging a deduction up to 2 points will occur. The vehicle should have adequate speed and distance control for this not to happen.

5. If the R2D2 unit falls off the cargo carrier, 30 points may be deducted.

6. Two scores will be recorded per run. One score is for the vehicle's meeting the requirements of the MCR traversing the track. The other score will be the Energy/Mass ratio.

7. The final test is NOT a graded item in the gradebook but is a graded item in the Critical Design Review (CDR) Report.

AEV Final Testing Scoresheet

Team/Team Name: ___________________________ Instructor: __________________Class Time: ______________

This sheet must be filled out and signed by a member of the Instructional Staff by the end of Lab. The Instructor/TA must watch the AEV complete the operational objectives and will record the results below.

		Run 1			Run 2		
Procedure		Yes	No	PTS Earned	Yes	No	PTS Earned
Team shows proper testing procedure (up to 10 points)				/10			/10
AEV starts and travels to first gate				/4			/4
Gate Routine	Stops before gate			/4			/4
	Waits 7 seconds			/4			/4
	Travels through gate			/4			/4
AEV starts and travels to loading zone and waits for 5 seconds				/4			/4
AEV connects to cargo & travels to gate (crashes into cargo-deduct <= 2)				/4			/4
Gate Routine	Stops before gate			/4			/4
	Waits 7 seconds			/4			/4
	Travels through gate			/4			/4
AEV starts and travels to starting point				/4			/4
Total Points Earned				/50			/50
Total Score = Total Pts Earned * Δt					Max Total Score		

Track Layout: ___________
(Inside or Outside)

Mass of AEV: ___________
(in kilograms)

Total Energy: ___________
(Joules)

Total Time Run1: _________
(seconds)

Total Time Run2: _________
(seconds)

Delta Time Run 1:

$$\Delta t1 = 1 + \frac{150 - \text{total time}}{150}$$

= _________________

Delta Time Run 2:

$$\Delta t2 = 1 + \frac{150 - \text{total time}}{150}$$

= _________________

Energy/Mass: ___________
(Joules per kilogram)

Your final score will be based on the **Energy/Mass ratio** (how efficient is the team's AEV) and the **Total Score** (time and distance requirements).

Instructor / TA Signature: ____ Date: _________________

Critical Design Review (CDR) Report

(Due Lab 12C: Oral Presentations)

Write a Lab Report

For details on content and formatting, see the Technical Communications Guide on Lab Report specifications.

Executive Summary

- Provide the research focus on the need for an Advance Energy Vehicle. Address the overall goals and objectives.
- Briefly discuss the research methods used to obtain results.
- Discuss major results and findings from the Performance Tests 1-3 to help obtain the final design vehicle.

Results & Discussion

- Provide a brief description of the group's two prototype AEV concepts used in Lab 08: Performance Test 1 – Design (include a figure of each concept in the report). Describe the evolution of the concepts in Lab 01: Creative Design Thinking to the two prototypes in Performance Test 1 to the final product.
- Provide a screening and scoring tables (Lab 03: Concept Screening and Scoring) to help defend the final design to all concepts and prototypes.
- Discuss the cost of the system. What was done to reduce the cost of the overall system?
- How did this Performance Test affect the team's design process? Discuss the results from the design cycle and the energy optimization during the performance tests.
- Incorporate the following figures into the discussion (from both AEV prototype concepts):
    - *System Efficiency vs. Advance Ratio* from wind tunnel testing similar to the one constructed in System Analysis 1 to help aid in the team's decision in the propeller used
    - Figure of supplied power vs time/distance (team can pick either to plot vs. time or vs. distance).
    - *Table that has a breakdown of Supplied Energy* for each line of code of the AEV's operation (each phase of the vehicle's motion that consumes energy)

** Make sure you include a brief discuss of the figures and tables. Verify that the figures and tables are labeled correctly with appropriate units, title, and x- and y-axis labels **

- What observations did the team make during final testing? How did the AEV behave? How efficient was the vehicle? This is where you discuss the scores on the final test score sheet (include the team's scoresheet in the Appendix).

Note: if the AEV did not finish the final test, discuss why it did not complete the scenario and provide reasons not excuses to why.

Conclusion and Recommendations

- Develop a thoughtful yet concise conclusion from the results obtained in the course.
- Summarize important results from the report.
- Defend the final design and discuss why the team's AEV is the best design compared to the rest of the class (what advantages does the team's AEV have?).
- Provide any recommendations for improvements to the AEV project.

Appendix

- Provide the group's project schedule for the entire semester: start and end dates, due dates, the group members percent completed, their roles for tasks that need to be completed, and the percentage completed (See Technical Communications Guide for example).
- Provide the SolidWorks model of the final design and ensure that the figure has the 3 primary orthographic views with overall dimensions, estimated weight, estimated cost,

Grading Rubric – Critical Design Review (CDR)

Instructor:____________________ GTA:____________________ Group:_____

Content

Section	Background		Results		Recommendation		Total
Abstract	3	Purpose Identified	4	Clear & concise	3	Direct & justified	
	2	Purpose not clear	2	Wordy and/or unclear	2	Unclear and/or weak	
	0	Poor / missing	0	Poor / missing	0	Poor / missing	___ 10

Section	Purpose		Background		Total
Introduction	4	Good / restated	4	Complete	
	2	Poor / copied	2	Incomplete / not specific	
	0	Missing	0	Missing	__ 8

Section	Procedure		Equipment		Total
Experimental Methodology	3	Could replicate experiment	3	Thorough description w/ pictures or diagram of setup	
	2	Some details missing	2	Setup unclear or equipment left out	
	1	Missing several important steps	1	Missing pictures/diagrams	
	0	Exceedingly poor	0	Exceedingly poor	___ 6

Section	Objectivity		Observations		Data Placement		Total
Results	2	Objective results	2	Objective observations	4	Easy to find	
	1	Some subjectivity	1	Some subjectivity	2	Some difficulty	
	0	Mostly subjective	0	Missing	0	Mostly hidden	__ 8

Section	Data Analysis		Tables & Figures		Total
Results	4	Logical steps / thoroughly explained	16	Good use of tables and figures	
	2	Difficult to follow or missing critical steps (i.e. sample calculations)	8	Needs more/fewer tables/figures	
	0	Exceedingly poor	0	Exceedingly poor	__ 20

Discussion	Analysis		Potential Error		
	4	Clear trends identified & relate to purpose	3	Reasonable / well justified	
	2	Trends unrelated to purpose / some missing	2	Unreasonable / poorly justified	
	0	Exceedingly poor / missing	0	Exceedingly poor / missing	__ 7
	Comparison to Theory		**Defense of Final AEV Model**		
	4	Quantitative and logical	5	Justified w/ data & theory of matrices	
	3	Qualitative or illogical	3	Justified w/o data or theory of matrices	
	2	Poor / Lacking critical details	2	Not fully reasoned / verified	
	0	Exceedingly poor / missing	0	Exceedingly poor / missing	__ 9
	Screen AND Scoring Matrices		**Observations from Final Run**		
	3	Justified w/ data & theory	3	Justified w/ data & theory	
	2	Justified w/o data or theory	2	Justified w/o data or theory	
	1	Not fully reasoned / verified	1	Not fully reasoned / verified	
	0	Exceedingly poor / missing	0	Exceedingly poor / missing	__ 6

Conclusion & Recommendations	Summary		Conclusions		Resolving Error		
	7	Summarized experiment, results, & discussion	7	Supported by data & relevant to purpose	6	Addresses error / reasonable	
	5	Summary lacking in parts or missing critical part	5	No link to results / discussion	4	Unaddressed or unreasonable	
	3	Poor / missing two parts	3	Lacking critical thinking	2	Poor / Lacking thought	
	0	Exceedingly poor / missing	0	Very poor / missing	0	Missing	__ 20
	Recommendations		**Reasons for Incompleteness**		**Format & Language**		
	7	Well thought out / reasoned	7	Justified w/ data, theory, & suitable references	6	< 2 mistakes in format < 2 mistakes in language	
	5	Not fully reasoned	5	Justified w/o data or theory or references	3	4-6 mistakes in total	
	3	Very poor	3	Not reasoned / verified	0	> 6 mistakes	
	0	Missing	0	Very poor / missing			__ 20

	Schedule		SolidWorks Models		
Appendix	18	Has completed/start/end dates, group members, percentage completed, roles, tasks, and estimated hours. Formatted Correctly	18	Has final model with bill of materials, overall dimensions, weight, cost and 3 views	
	12	Lacking a few of components from above	12	Lacking a few of components from above	
	9	Has very basic information, formatting issues	9	Missing prototype / has very basic information	
	5	Lacking or exceedingly poor	5	Exceedingly poor	
	0	Missing	0	Missing / Hand drawn	___ 36

Format & Language

	Body Content		Appendix Content		Total
Content Placement	4	All in correct sections	4	Appropriately placed	
	2	Minor misplaced content	2	Minor misplaced content	
	0	Large sections of misplaced content	0	Too much content in appendix	___ 8

	Labels & Placement		Referencing		
Labels & References	4	All present w/descriptions & placement	4	Well referenced & described in body	
	2	Some missing or poor descriptions	2	Poor descriptions and/or references	
	0	Missing or no description	0	Missing references	___ 8

	Errors		Citations		
General Format	4	Fewer than 2 mistakes	3	Proper citations	
	2	2-5 mistakes	2	Few citation mistakes	
	0	More than 5 mistakes	0	Poor / missing citations	___ 7

	Brevity		Clarity		Flow		
Structure1	4	Concise	4	Clear	4	Smooth	
	3	Some wordy areas	3	Few parts confusing	3	Few disjointed parts	
	1	Very wordy	1	Many parts confusing	1	Many disjointed parts	
	0	Exceedingly Poor	0	Confusing overall	0	Very disjointed	___ 12

	Professionalism		Tense / Person		
Wording	5	No slang, jargon, etc.	5	No slips in tense/person	
	4	Some slips in professionalism	4	1-3 slips in tense/person	
	2	Distracting / poor	2	4-8 slips in tense/person	
	0	Exceedingly poor	0	More than 8 errors	___ 10

	Spelling / Grammar / Punctuation		
General	5	Minor errors	_ 5
	3	Few errors, but not distracting	
	1	Distracts from readability	
	0	Complete lack of proofreading	

Writing Total	/ 50
Content Total	/ 150
Total	/ 200

Instructor / GTA End-of-Lab Signoff

CDR: ____________________________________

Lab 12: Oral Presentation

Purpose:

This assignment is a chance for you to share information about your unique Advanced Energy Vehicle (AEV) with the entire class for their benefit via an oral presentation (with visuals). The oral presentation covering the AEV project is an opportunity for each student team to practice communicating their ideas concisely and in a way that is captivating to the audience.

Assignments and Grade Breakdown (See following sections for details):

1. Draft of visuals and plan for the AEV Oral Presentation **(25 pts.)**
2. AEV Oral Presentation **(100 pts.)**

Approximate Working Timeline (Check course website for actual due dates):

- **Lab 10C:** Team submits Draft for Oral Presentation
- **Lab 10C:** Receive feedback from GTA
- **Lab 13B/C:** Team gives Oral Presentation on AEV Project

Assignment Detail:

A detailed layout of the process leading up to the oral presentation on ethics and the work involved follows.

1. **Discussing AEV Design**

   Teams are required to prepare and present on their AEV design.

2. **AEV Outline (25 pts.)**

   After the team has completed the bulk of the AEV design, the team is required to create a draft of the oral presentation. Make sure to include as much detail as possible. The team will be evaluated based on:

   a. The overall organization of the contents of your presentation material - Arrange the presentation materials such that the subsequent topics are connected and have a smooth flow.
   b. The approximate amount of time the team will spend on each topic.
   c. The order in which the team members plan to present.

   The team will receive to feedback and remember to incorporate the Instructor/GTA's recommendations when planning for the actual presentation. Refer to the Oral Communication Section in the *Technical Communication Guide* for tips on how to plan for your presentation. This **<u>draft should be a close approximation of what you are planning for your presentation</u>**. In grading this, GTA's will be looking at content covered, formatting of the slides (e.g., **font, font size, slide color, font color,** etc.), aesthetics and length. There is no minimum/maximum number of slides required; however, keep in mind that the presentation must be eight minutes in length with two minutes set aside for audience questions and answers.

Grading of AEV worksheet:

ITEM	**POSSIBLE POINTS**
OUTLINE FORMAT	5
CONTENT AREAS	5
SPEAKERS LISTED	10
EFFORT/NEATNESS	5

Oral Presentation (100 pts.)

The actual presentation should last no more than eight minutes (approximately evenly divided among the team members) and teams should allow no more than two additional minutes for questions and answers. Please refer to the sample oral presentation in the *Technical Communication Guide* along with the following oral presentation evaluation sheet (below) for specific guidelines.

The oral presentations will occur over two days (Labs 12 B and C). The instructor/GTA will decide which team will go on what day.

ENGINEERING 1182: Oral Presentation Evaluation Form (AEV)

Team Letter:

Team Members:

General Quality of Presentation

		________	________	________	________	________
1	**Poise and professionalism** (Appropriate attire, posture, gestures, visibility, position, etc.)	0 2 4 6 8 10	0 2 4 6 8 10	0 2 4 6 8 10	0 2 4 6 8 10	0 2 4 6 8 10
2	**Delivery and clarity** (Eye contact, voice level/inflections, rate of speech, enthusiasm, understanding of topic, emphasis on relevant items, etc.)	0 3 6 9 12 15	0 3 6 9 12 15	0 3 6 9 12 15	0 3 6 9 12 15	0 3 6 9 12 15
	Individual Score (25 max)	________	________	________	________	________

Content (Team Score)

Comments:

1	**Introduction and summary of presentation** (Introduction of team members; overview slide)	0 2 4 6 8 10
2	**Description of team's design process** (Including pictures drawings, sketches)	0 3 6 9 12 15
3	**Performance: energy and efficiency** (Data tables and plots)	0 3 6 9 12 15
4	**Discussion of final design** (Pictures, sketches and/or a short video)	0 3 6 9 12 15
5	**Overall slide quality / readability / effectiveness** (Amount of text, font size and style, slide layout)	0 2 4 6 8 10
6	**Team stayed within allotted time and answered questions effectively** (8 minute talk + 1-2 minutes Q&A)	0 2 4 6 8 10
	Team Score (75 max)	________

Additional Comments on Back of Sheet

Total score - each student ________ ________ ________ ________ ________

Appendix A – Creative Design Thinking Techniques

There are many additional techniques used both in industry and academia to generate and promote ideas as described in Background: Creative Design Thinking. Some of these techniques to generate ideas or solutions are (but not limited to):

1. **Notebook**
2. **Brainstorm**
3. Attribute Listing
4. Drawing
5. Construction
6. Research and Lateral Thinking
7. Assumption Smashing
8. Fail Fast

A detail description of the techniques can be seen below. The notebook and brainstorming techniques are described in detail in Background: Creative Design Thinking. These definitions and techniques have been adopted from the Multidisciplinary Design Capstone Program and Mechanical Engineering's Industrial Design Courses.

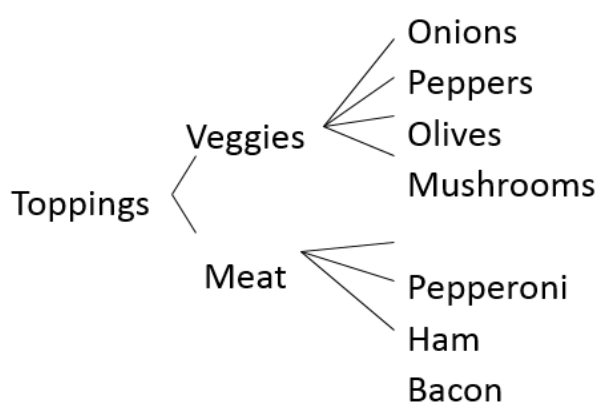
Attribute Listing: The different components can then be brought together to form a whole.

Attribute listing is intended to create a very exhaustive list. Classification Tables and Classification Trees are ways of organizing these options. Classification tables are more often used when only one choice will be made from each list. An example of attribute listing of both a classification table and tree is illustrated below.

Classification Table:

Crust	Vegetables	Meat
Hand tossed	Onions	Pepperoni
Pan	Peppers	Ham
Wheat	Olives	Sausage
	Mushrooms	Bacon

Classification Tree:



Drawing: Drawing or doodling allows the unconscious mind of ideas come to the surface. Detailed drawings are good for refining doodles and communicate ideas. Other types of drawing include storyboarding and mind mapping. Storyboarding is a method of organizing parts or subsystems each represented on a separate sheet. This technique allows the designer to arrange drawings and see interactions between the different components. With storyboarding, one can see the product in its intended environment/function. Storyboarding has been an important tool of the movie and television business for years. Today it is also used with web page design, but the concept could be applied to instruction manuals or even any product design that requires the consumer to complete a sequence of tasks. Mind mapping is defined as a graphical way to represent ideas or concepts. Mind mapping combines the typical linear notes and a classification tree. Mind map is created with a central idea with subtopics branching off from the central idea. An example of mind mapping is describing the process of mind mapping:

Source: fotolog.com

Construction: Constructing 2-D and 3-D solutions will often help the designer to visualize the problem and possibly see aspects of the problem that would otherwise be overlooked. Velcro Boxes: Represent the product as a large surface and supply “controls” of all shapes and sizes that can be placed anywhere and given any function. The key is to have a good sized supply of different shapes and sizes so that the creativity is not stifled. Similar concept generating exercises can be done using construction paper (2-D), but Velcro modeling is preferred because it is a 3-D representation. Foam models are generally created as visual representations and do not allow for ‘rearranging’ of the product’s features.

Research: there are multiple ways to research. The top three conventional ways to research include web searches, patents, and solutions to similar problems. Web searches tend to be very convenient for students since they have access to computer facilities. However, searching articles and books is also important. A patent is a grant for an invention by the government to the inventor in exchange for full disclosure of the invention. Patents are considered tangible assets that can be bought, sold or traded. Designs of substance, apparatuses and industrial processes can be patented, but artistic creations, mathematical methods and business schemes cannot. Studying existing patents can lead a researcher to propose improvements that are themselves patentable. Patent information contains a technical solution to a given problem, detailed workings of the invention and any possible defects in prior designs. By studying patent information a designer can save time and money. Patent information can be located in any library as well as on the web at http://www.uspto.gov.

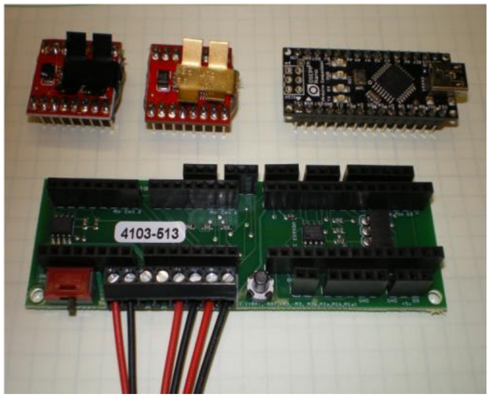
Assumption Smashing: Often there are trade-offs involved with a design. Perhaps something that seems like a constraint really isn't. For example, if an assembly contains both a plastic component and a metal spring the assumption that the spring must be metal can be dropped and the two pieces can be molded as one plastic part. Boothroyd and Dewhurst devised a "Design for Assembly" part reduction chart based on these principles, where each part of the design is analyzed and the possibility of combining it with another part is considered.

Fail Fast: Is a technique of trying something quick and provides fast feedback. This technique allows for rapidly inspecting and adapting the design to meet the constraints. When the uncertainty of the solution to the problem is high, this technique tends to be less expensive. This technique is observed a lot in computer coding. An example of this technique could be the following (trial-and-error):

> Code in Arduino for the AEV to go 5% power. Ran the AEV and determined that at that power setting, the AEV does not travel anywhere. Go back into Arduino and code the AEV to go 10% power. Ran the AEV and determined at this power setting the AEV starts to move.

Title	Instructor		Scale
Name	Seat	Hour	Date

Appendix B – AEV Controller



Created by Lowell Toms.16

Light Weight

- 23 grams (bare motherboard)
- 43 grams (w/ cables, Arduino, motor controllers)

Small Size

- 1.2 inches wide x 3.7 inches long x 0.625 inches high
- Mounting hole spacing is 1 by 3.5 inches

Simple Microcontroller with Easy to Use Software

- Arduino Nano microcrontroller
- http://www.gravitech.us/arna30wiatp.html
- Uses the open source Arduino Integrated Development Editor (IDE)
- Software available from http://arduino.cc/

High Motor Output Currents

- Ability to supply 2 amps (3 amp peak) per motor
- Uses parallel operation of the TB6612FNG motor driver
- https://www.sparkfun.com/products/9457

Current and Voltage Sensing

- Allow constant current and voltage sensing throughout a run
- Hall effect current sensor ACS715LLCTR-20A-T
- Simple 10K/10K/10K voltage divider allows for monitoring of batteries up to 15 volts

Extra memory to record voltage and current for a two minute run at 50 ms intervals - Additional 32k bytes of eeprom memory (24LC256, uses i2c bus)

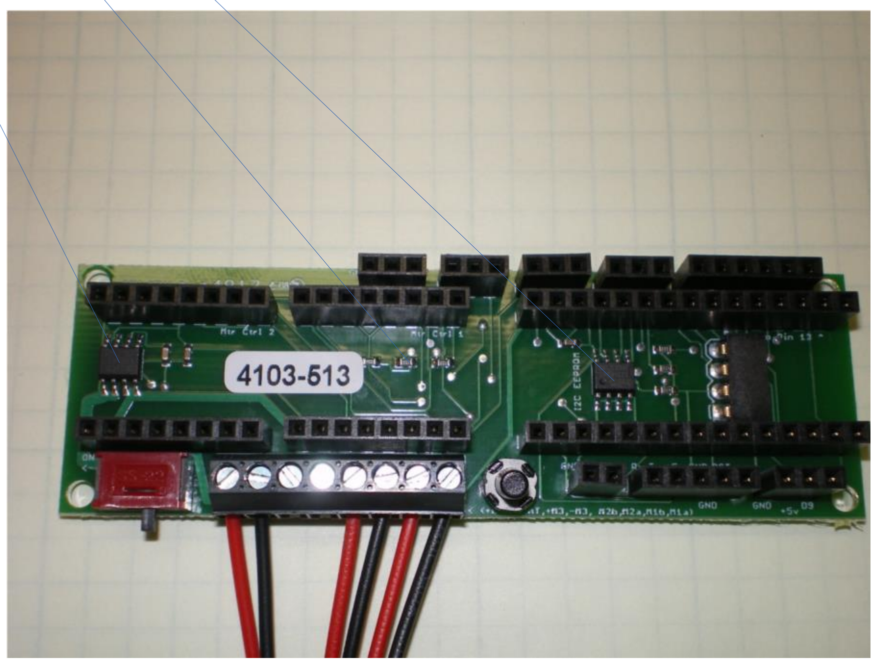
Low Cost

- ~$75 (not including development cost)

Motherboard Active Surface Mount Parts

The current sensor, voltage divider, and external eeprom memory are located directly on the motherboard.

- Hall Effect current sensor, ACS715, is located just under motor control chip #2 (sensed by pin A6).
    - Three resistor voltage divider (10K/10K/10K), sensed by pin A7.
        - External eeprom, 24LC256T-I/SN, using the i2c bus (pins A4 and A5).

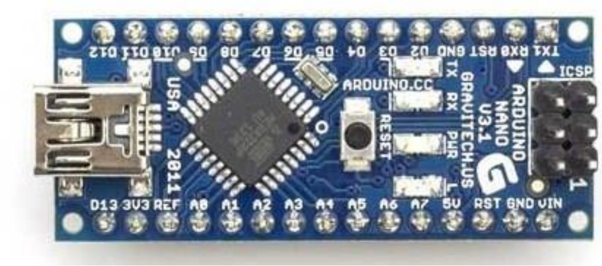


External Parts and Assembly

The AEV motherboard pulls together three commercially available electronic daughter boards thus leveraging the design work and production level discounts of these devices. The heart of the AEV controller is the Arduino Nano 3.0 board manufactured by Gravitech: http://store.gravitech.us/arna30wiatp.html

The Arduino Nano uses and open source design accepted by the Arduino foundation.

http://arduino.cc/en/Main/ArduinoBoardNano

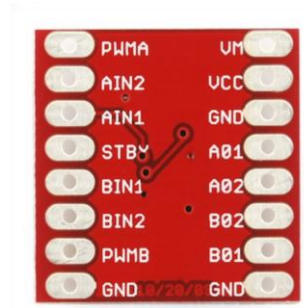


The Nano differs from the Arduino UNO in that it still uses the FTDI USB to serial converter and breaks out an additional two analog pins from the Atmel 328 microprocessor chip. It is a 5 volt device with 12 usable digital pins (2-13), and 8, 10bit, analog pins (A0-A7), the first six of which can also be used as digital pins by addressing them as 14-19. The pin out of the Nano is provided in Pin Usage.

The Arduino Nano controls the current provided to the recommended E-Flite EFLH1322 direct drive motors by using the built-in Pulse Width Modulation (PWM) of the Nano that is decoded by the Toshiba motor control chip. The chip also provides an integrated H bridge providing for current reversal (motor reverse). These surface mounted motor control chips, TB6612FNG, are placed on a breakout board by Sparkfun:

https://www.sparkfun.com/products/9457

The motherboard design allows the surface mounted moor control chips to be easily replace if damaged.

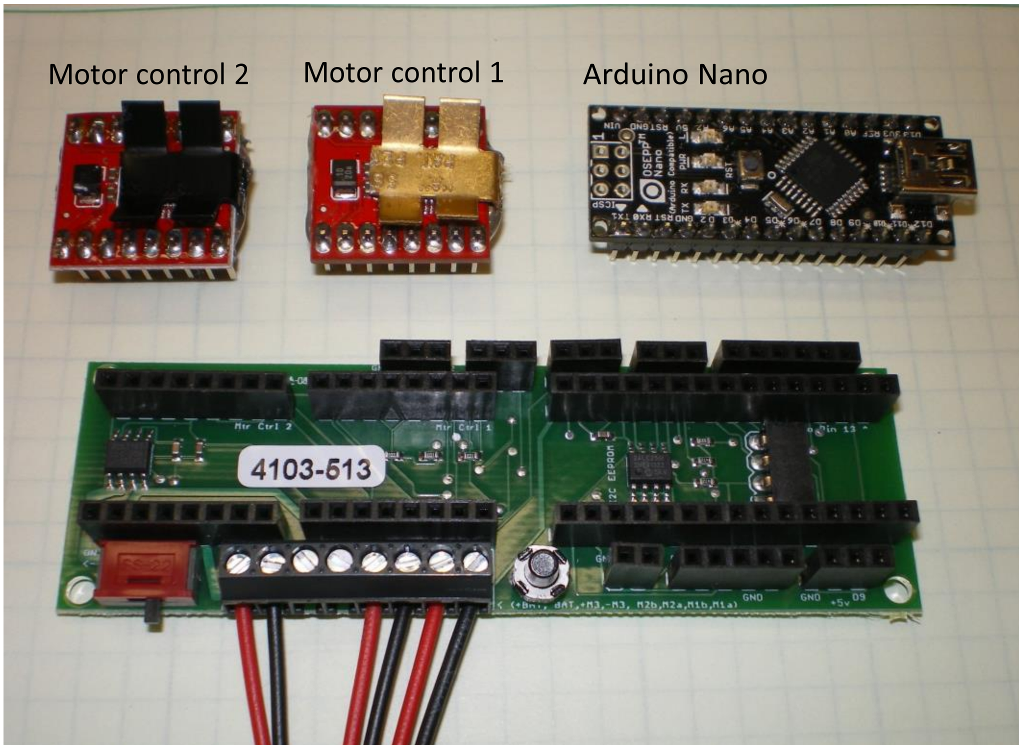


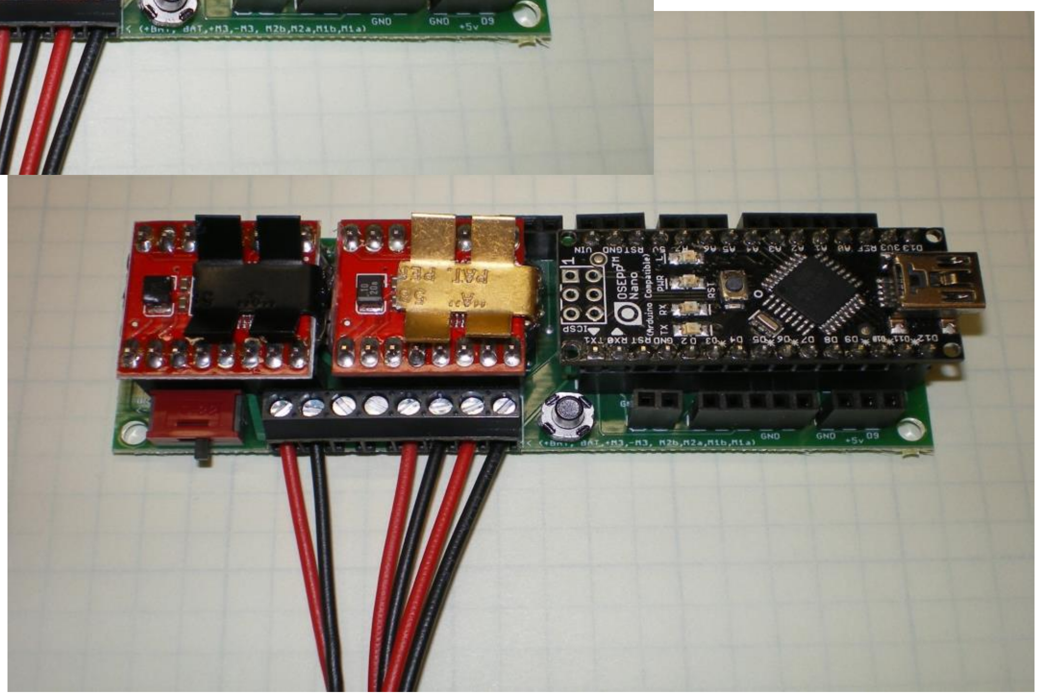
The Toshiba motor control chips can handle two motors at 1.2 amps each, but the AEV mother board ties these two circuits together in parallel to give 2.4 amps for a single motor, i.e. the following inputs are tied together:

- Ain1 and Ain2 (H bridge input control logic)
- Bin1 and Bin2 (H bridge input control logic)

- PWMA and PWMB (PWM input signal)
- A01 and B01 (motor lead output)
- A02 and B02 (motor lead output)

The Arduino Nano and the two motor control chips mount to the mother board as shown below:





Heat sinks were added to the motor control chips to help control over temperatures during extended high speed runs. The heat sinks are modified Di gikey parts.

Pinouts

Motors

The Arduino Nano has 12 usable digital pins (D2-D13), and 8 usable analog pins (A0-A7). Analog pins A0 to A5 can be used as either an analog inputs (called as A0-A5) or as a digital pins (called as 14-19). Each motor requires a specialized digital pin capable of sending a PWM signal for speed control, and two digital outputs to control the H-bridge for reversing and braking. The Toshiba TB6612FNG h-bridge logic is shown in the following table taken from the device data sheet:

H-SW Control Function

Input				Output		
IN1	IN2	PWM	STBY	OUT1	OUT2	Mode
H	H	H/L	H	L	L	Short brake
L	H	H	H	L	H	CCW
		L	H	L	L	Short brake
H	L	H	H	H	L	CW
		L	H	L	L	Short brake
L	L	H	H	OFF (High impedance)		Stop
H/L	H/L	H/L	L	OFF (High impedance)		Standby

To conserve pins, the STBY pin is wired HIGH (+5 volts), so the “Standby” state is not available. The pins used are:

Motor	IN1	IN2	PWM
1	7	8	5
2	16	17	6
3	10	12	11

Motor 3 is an optional device; pins 10, 11, and 12 are merely brought out to a pin header. The location of these pin outs are shown in the Pin Header Breakout section.

Voltage Sensing

Analog pin 6 (A6) is used to sense the voltage on the last junction prior to ground of a 10K/10K/10K series resistor voltage divider connected from battery '+' to battery '-' also tied to Arduino ground. A voltage divider is used because the recommended battery, an E-Flite EFLB8002SJ30, two cell Lipo has a charge voltage of about 8.4 volts. The Arduino Nano analog pins can sense voltages up to a maximum of 5 volts. By using the three resistor voltage divider, a LiPo 2 cell or 3 cell battery can be monitored by simply multiplying the sensed voltage by three. Here is an example calculation:

3*ADC counts*5/1024 = battery voltage

AnalogReference must be set to “DEFAULT,” and at least one analog sample taken, prior to sampling the battery voltage.

Current Sensor

The ACS715 current sensor uses the same circuit configuration as the Pololu part number #1186, however the Pololu part is a 30 amp chip and the part used for the AEV is a 20 amp model. Analog pin A7 monitors the output voltage of the ACS715 which outputs a nominal 0.5 volts at 0 amps and increases in voltage by 0.185 volts per amp. To increase the resolution of the 10 bit analog to digital converter while sampling the current sensor, the external reference pin is pulled down to 2.46 volts, (5*32K)/(32K+33K)=2.46 volts , instead of the default 5 volts by using a 33K resistor tied to ground. The actual calculation is explained here.

The software collects the initial ADC count (ADCi) prior to the run which corresponds to the 0.5 volts at zero amps. During the run the current calculation in amps is:

(2.46*(ADC counts-ADCi)/1024)/0.185 = amps

AnalogReference must be set to “EXTERNAL” and at least on analog sample must be taken prior to sampling the current sensor.

Wheel Count Sensors

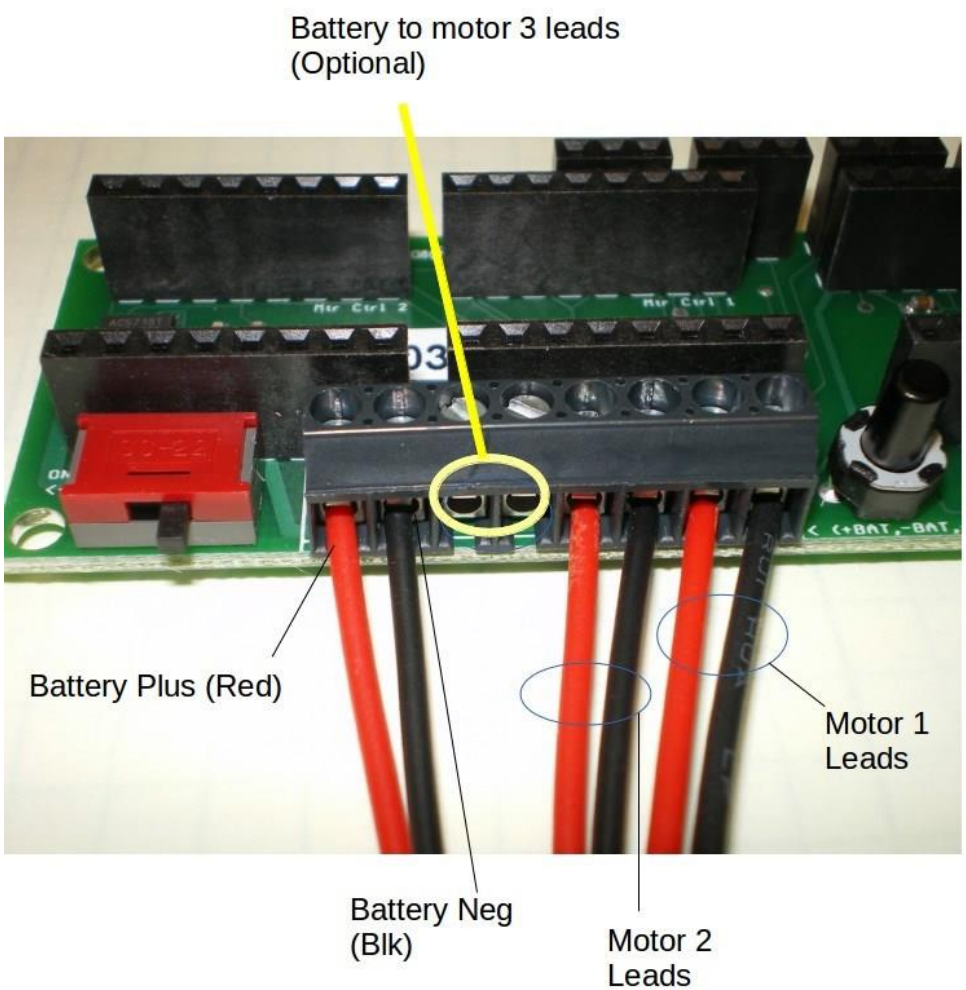
The system software has the ability to use digital pins 2 and 3 to monitor wheel rotation using a quadrature type encoder algorithim with reflectance type sensors, as shown in the immediate picture, using a wheel with alternating reflective and non-reflective surfaces. Wheel counting requires continuous background updating while the main program is running, and the Arduino Nano has two pins, digital 2 and digital 3, capable of handling interrupts,
Interrupts provide the necessary background processing triggers. Pins 2 (interrupt 0) and 3 (interrupt 1) are brought out on separate motherboard pin headers and shown in the 'Motherboard Headers' section.

Motherboard Pin Header Layout

This section shows the location of the broken out pins. Pin Usage is a table showing Arduino Nano pins and their use with the AEV project and whether or not they are broken out to separate headers on the motherboard. Some pins are not used at all, while others can be used for multiple items (buses). Usable pins have been broken out on the motherboard, usually in pin header groups of three, consisting of a signal pin, a +5 volt pin, and a ground pin.

Cables

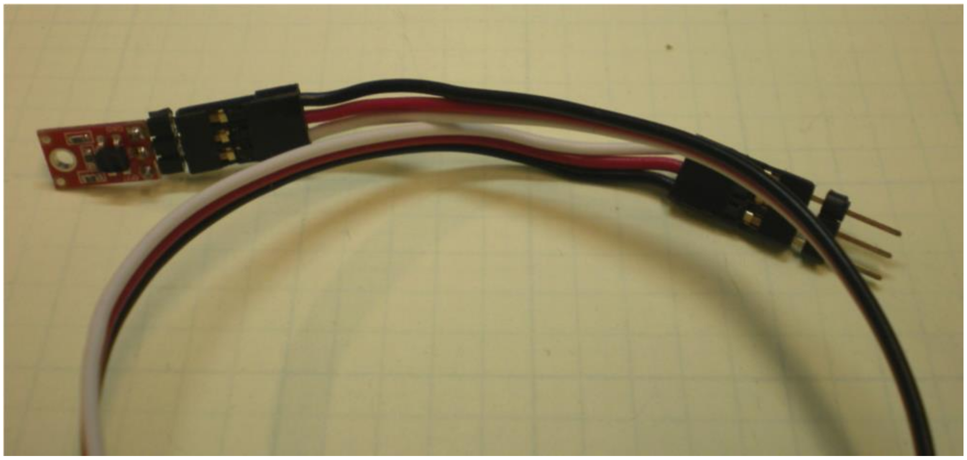
There are three JST cables (battery uses male JST) attached to the board, with room for an optional cable that would supply power to a separate motor control chip used for a third motor.



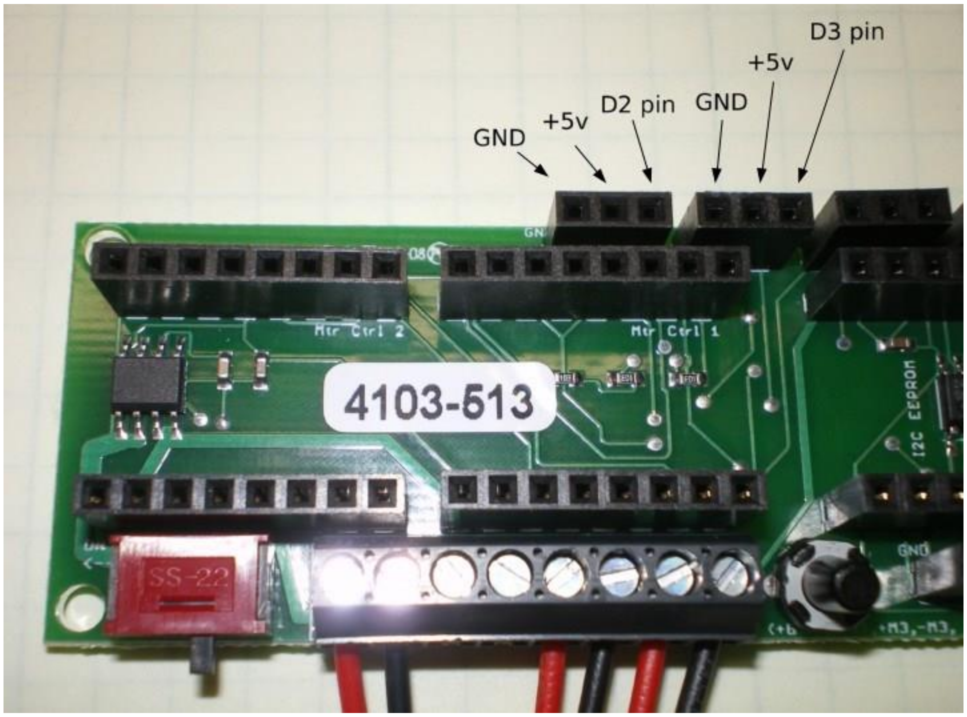
The motor cables are not polarity sensitive (just determines initial motor rotation direction). The battery cable is polarity sensitive and can easily destroy the entire board if wired backwards.

Sensor Pin Headers

As previously mentioned, digital pin 2, and digital pin 3 are interrupts used for background processing of the quadrature type wheel counter implemented in the AEV6 software. The provided sensors are attached to a three wire extension with wire colors of white, red, and black. For consistency, please make sure the black wire attaches to the labeled ground (GND) pin of the sensor.



The sensors attach to the following locations (black wire to ground, white to digital pin).

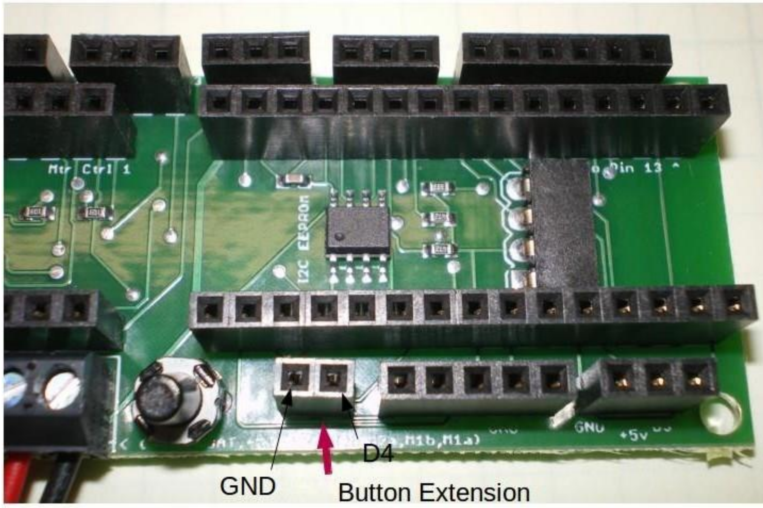


Shown below are the reflectance sensors attached to the wheel mounting strut. When using quadrature encoding, you will need to determine the proper sensor orientation by trail and error. If, when moving forward on the track, the track counts decrease or go negative, just swap the sensor locations (digital 2 plug and digital 3 plug).

Button Extender

The pushbutton mounted on the motherboard is held down for a second or so as a signal to the software to begin the run. This button may not be in a convenient location when the vehicle model is complete. The two pin female header located next to the button allows an extension to be run to a remote button. The button has no pull-up resistor associated with it. To use the button, the parallel implementation of D4 to GND on the button extension, make sure you use the proper pinMode setup command:

```
pinMode (4, INPUT_PULLUP) ;
```



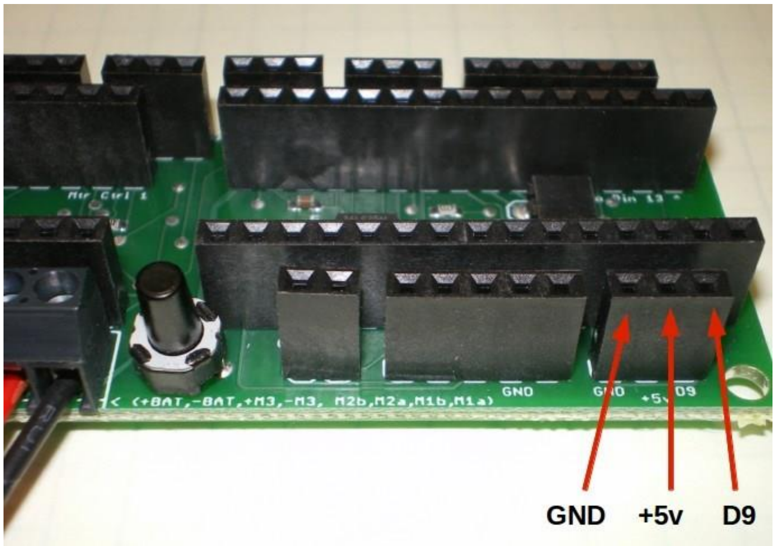
Servo Header

Digital 9 is often used for servo operation D9 is brought out on a three pin female header consisting of GND, +5v, and D9. Please note that microcontrollers have several clocks, but multiple process calls to a clock may cause conflicts.

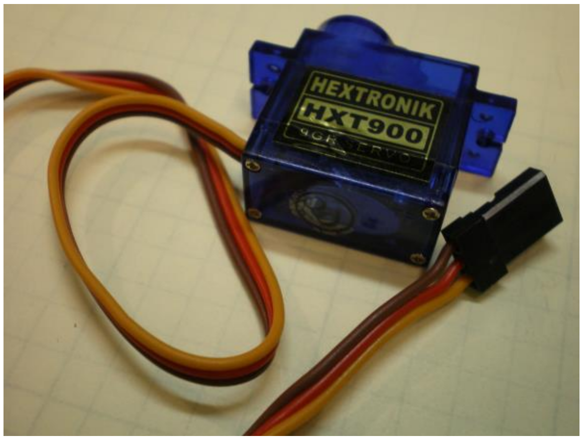
"On boards other than the Mega, use of the [servo] library disables analogWrite() (PWM) functionality on pins 9 and 10, whether or not there is a Servo on those pins." (from Arduino Reference)

Thus the normal servo library could not be used if the optional third motor is employed. There are several alternate servo libraries that can be tried if a conflict is suspected:

http://playground.arduino.cc/ComponentLib/Servo
http://arduiniana.org/libraries/pwmservo/

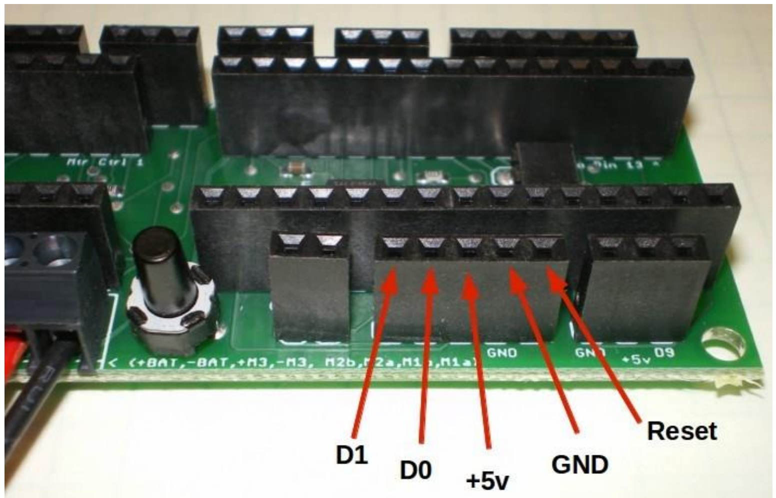


The mini-servo has brown, red, and orange wires. Brown is GND, red is +5v, and orange is signal (D9). Use male pin extender to join the two connectors.



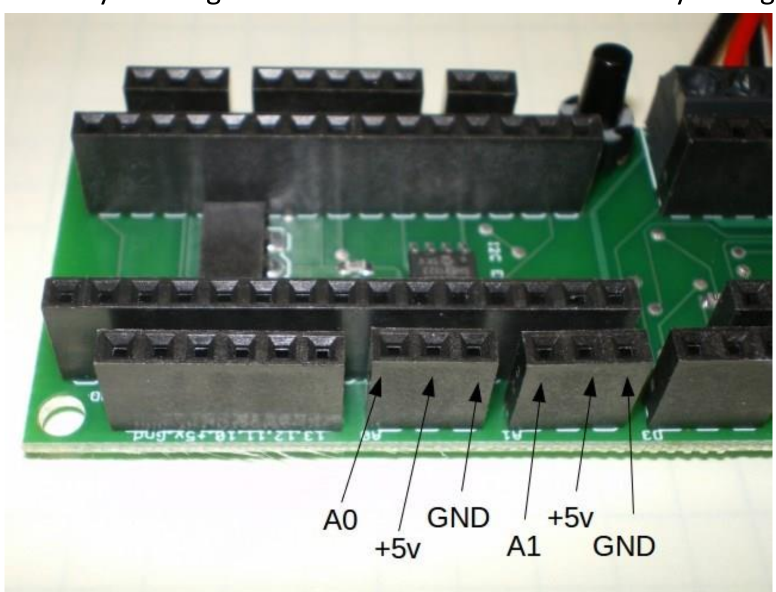
Wireless Header

The wireless header will have limited use, but it does allow for a wireless connection using the serial bus (D0, labeled as TX and D1 labeled as RX). Connecting to these pins will interfere with normal USB communications and should be avoided in most cases. The remainder of the this five pin female header includes a +5V pin, GND pin, and a hardware reset pin. In some cases it may be desirable to do a hardware reset. Connecting the reset pin temporarily to the GND pin will restart the microcontroller and then restart the program that has been flashed to the microcontroller. Unlike a software watchdog reset, all caches are flushed as well which is usually an advantage.



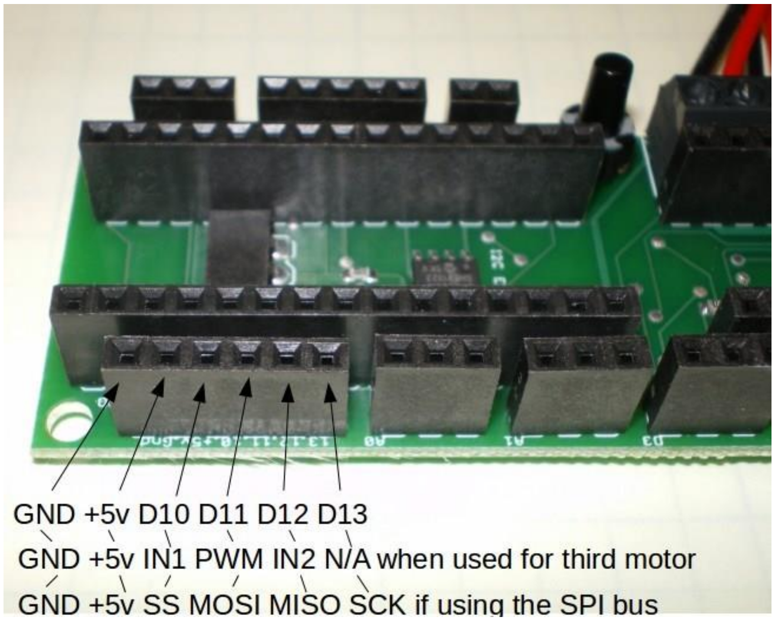
Unused Analog Pin Headers

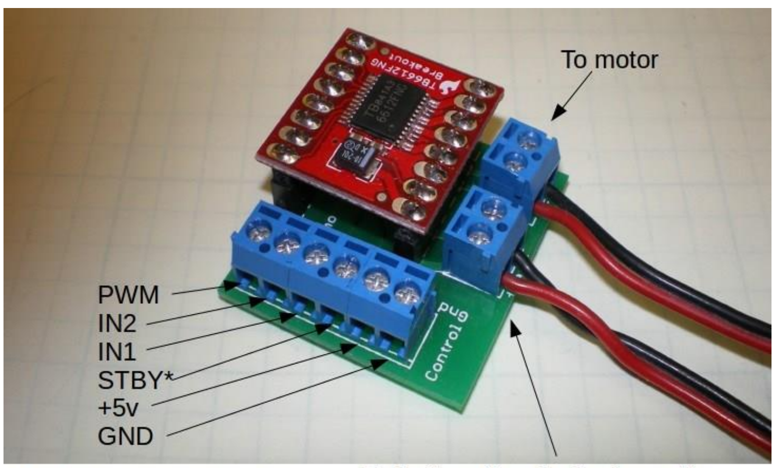
Two analog pins A0 and A1 are available for use. These pins can also be called as digital pin 14 and 15 respectively. Never place more than 5 volts on these pins. Battery voltage of a two cell LiPo used for this project is approximately 8 volts. Placing battery voltage directly on one of the Arduino pins will destroy that pin, which is why a voltage divider is used to measure battery voltage during the run.



Third Motor or SPI Header

The control section of the optional third motor can be connected as shown below:





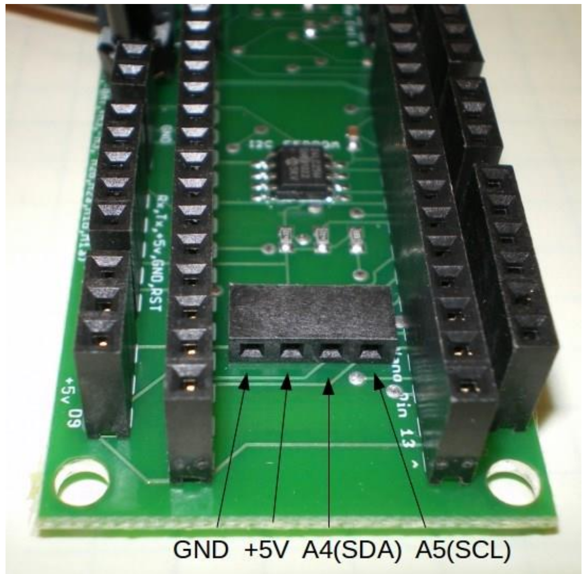
* STBY is shorted to +5v

To battery (terminal pair next to battery connector on motherboard)

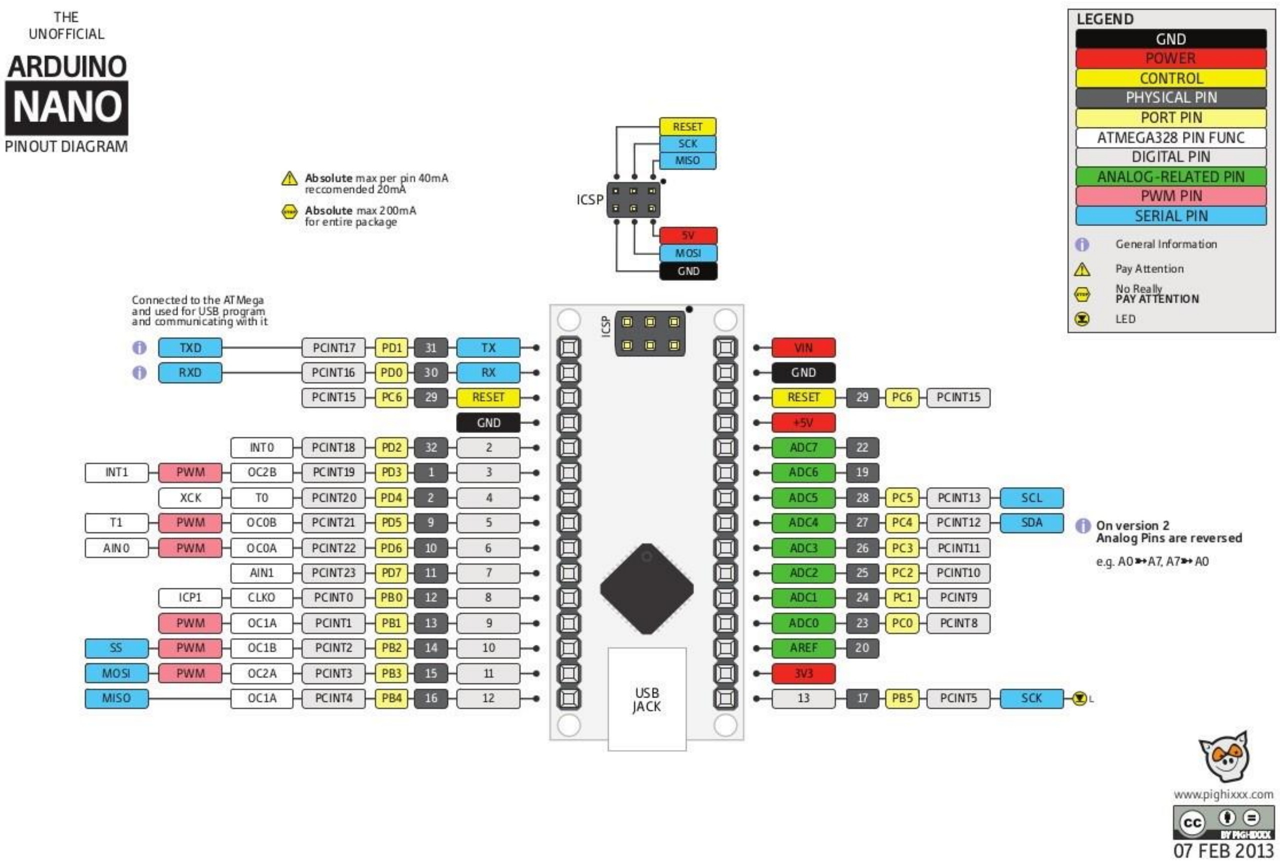
This same header can be used to access the SPI bus. The AEV software uses digital 13 as an indicator, conflicting with SPI use, but this could easily be overcome by using the D14 or D15 headers as indicators using an LED with a 330 ohm resistor current limiting resistor to ground.

I2C Bus Extension Header

The Arduino communicates with the external eeprom using the i2c bus (address 80). The i2c bus is addressable and can handle multiple items such as i2c displays, other addressable sensors, and sensor interfaces. Maximum wiring distance is about three feet.


GND
+5V
A4(SDA)
A5(SCL)

From: http://www.pighixxx.com/downloads/arduino-nano/



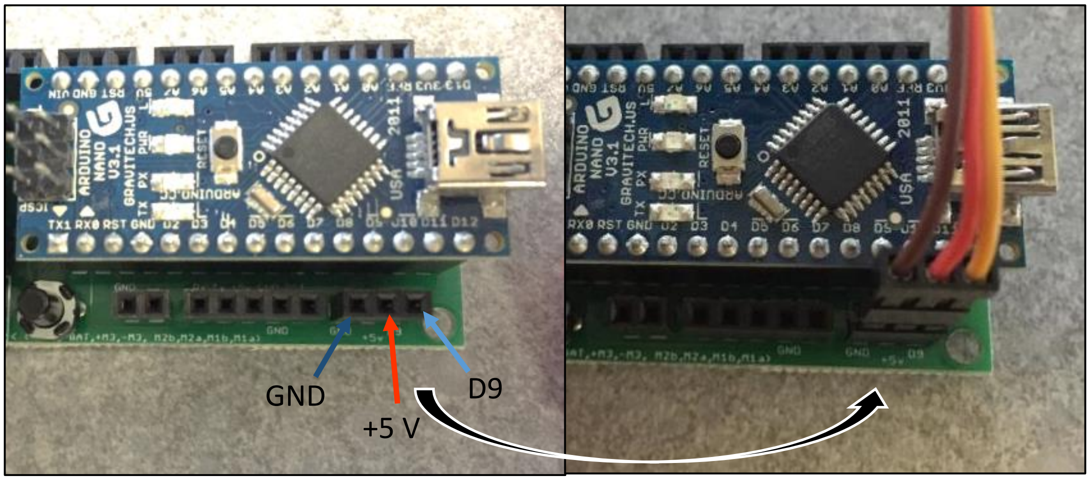
Pin Usage

AEV 6	Pin Usage	To Header?	Comment
D0	Serial Input/Reserved	Yes	Serial Input or Wireless Use Only
D1	Serial Input/Reserved	Yes	Serial Input or Wireless Use Only
D2	Interrupt 0	Yes	Used for wheel count sensor
D3	Interrupt 1	Yes	Used for wheel count sensor
D4	Button	Yes	Allows for remote
D5	PWM Motor 1	No	
D6	PWM Motor 2	No	
D7	H-bridge logic 1 for Motor 1	No	
D8	H-bridge logic 2 for Motor 1	No	
D9	Available	Yes	Possible servo usage
D10	H-bridge logic 1 for Motor 3	Yes	Available – SPI/CS
D11	PWM Motor 3	Yes	Available – SPI/MOSI
D12	H-bridge logic 2 for Motor 3	Yes	Available – SPI/MISO
D13	Built-in LED	Yes	SPI/SCK
A0/14	Available	Yes	
A1/15	Available	Yes	
A2/16	H-bridge logic 1 for Motor 2	No	
A3/17	H-bridge logic 2 for Motor 2	No	
A4/18	I2C-SDA for ext eeprom	Yes	eeprom uses addr 80
A5/19	I2C-SCL for ext eeprom	Yes	eeprom uses addr 80
A6/20	battery voltage sensor	No	
A7/21	current sensor	No	
REF	tied to 33K resistor to +5	No	EXTERNAL gives 2.46 volts

Appendix C – Servos with the AEV Project

Connecting the Servo to the AEV Controller

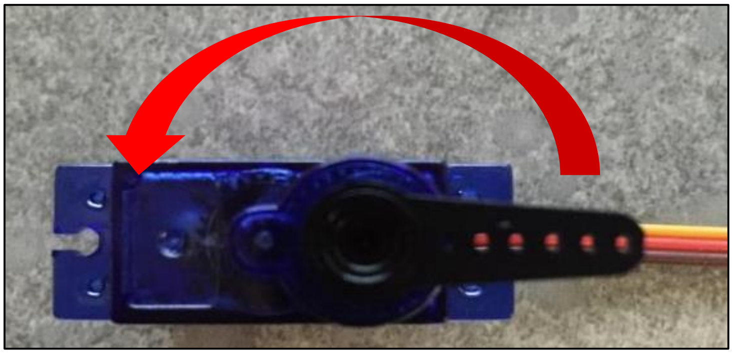
There is a special port for the servo to connect to on the AEV Controller board (This port connects to pin 9 on the Arduino Nano). Attached to the micro servo are three wires. The yellow wire is the wire that connects to pin 9, the red wire is power in, and the brown wire is ground. Simply connect the servo wire into the pin 9 port on the Arduino Controller.



Attaching a Servo Arm

1. Connect the AEV to a computer using the mini USB cable.
2. If there is no program on the AEV Controller, upload a program to the AEV Controller. It does not matter what code is under the myCode tab. (Note: If there is a program on the AEV Controller the servo will rotate when the AEV Controller is connected to the computer).
3. On startup, (when the power is turned on or the AEV is connected to a computer) the servo defaults to 0 degrees. This is the best time to attach a servo arm since the servo position is known.
4. From this position, the servo will rotate counterclockwise up to approximately 180 degrees. Let's test it!
   a. Open the Sweep program in sketchbook
      i. (File -> Sketchbook -> libraries -> PWMServo -> Sweep)
   b. Upload this program.
   c. Once it is uploaded the servo should constantly rotate between 0-180 degrees. If this works you're good to go!

5. Finally secure the support arm using the smallest of the three screws provided in the servo pack.



Attaching the Servo to the AEV

Servos can be attached to AEVs using screws, rubber bands, zip ties and/or electrical tape. NOTE: The group will be responsible for removing any adhesive material from any and all AEV components.

Using the Servo in the AEV_Controller Program

In the AEV_Controller program, select the _00_AEV_key_words tab. Function (h) “rotateServo” is the function used to controller the servo in your code. There is only one input required and that is the position between 0-180 degrees. See the description in the _00_AEV_key_words tab for further details and an example.

Appendix D – Wind Tunnel Spread Sheet

Lab 05: System Analysis 1

Wind tunnel air speed: ______________ m/s

Propeller configuration: ______________

Battery (Power Supply Setting): 7.4 volts

Table 1: Wind Tunnel Testing Data

Current	Thrust Scale Reading	RPM	Arduino Power Setting
amps	*grams*	*RPM*	*%*
			0
			10
			15
			20
			25
			30
			35
			40
			45
			50
			55
			60

Table 2: Wind Tunnel Data Analysis

Thrust Calibration	RPM	Power Input	Power Output	Power Output	Propulsion Efficiency	Advance Ratio
grams	*RPM*	*Watts*	*Horsepower*	*Watts*	*%*	*--*

Appendix E – Supplemental Material

AEV Checklist

Propulsion System

	# Given	# Returned	Unit Price	Amount Owed	Replacement Tally
Arduino	1	0	$100.00	$100.00	0
Electric Motors	2	0	$9.99	$19.98	0
Servo Motor	1	0	$5.95	$5.95	0
Count Sensor	2	0	$2.00	$4.00	0
Count Sensor Connector	2	0	$2.00	$4.00	0
Propellers	4	0	$0.45	$1.80	0

Body Structure

	# Given	# Returned	Unit Price	Amount Owed	Replacement Tally
T-Shape	1	0	$2.00	$2.00	0
X-Shape	1	0	$2.00	$2.00	0
2"x6" Rectangle	2	0	$2.00	$4.00	0
2.5"x7.5" Rectangle	1	0	$2.00	$2.00	0
1"x3" Rectangle	4	0	$1.00	$4.00	0
1.5"x3" Rectangle	3	0	$1.00	$3.00	0
Trapezoids	4	0	$1.00	$4.00	0
L-Shape Arm	1	0	$3.00	$3.00	0
T-Shape Arm	1	0	$3.00	$3.00	0
Wheels	2	0	$7.50	$15.00	0
Battery Supports	2	0	$1.00	$2.00	0

Brackets & Tools

	# Given	# Returned	Unit Price	Amount Owed	Replacement Tally
Angle Brackets	12	0	$0.84	$10.08	0
Screw Driver	1	0	$2.00	$2.00	0
1/4" Wrench	1	0	$2.00	$2.00	0
Motor Clamps	2	0	$0.59	$1.18	0
#55A Slotted Strip, 2"	8	0	$1.26	$10.08	0

Hardware

	# Given	# Returned	Unit Price	Amount Owed	Replacement Tally
Bulk Screws & Nuts	1	0	$2.88	$2.88	0

*Note: Individual screws and nuts do not need to be counted. If students return a reasonable amount, mark the '# Returned' as 1.

Instructor: ____________________

GTA: ____________________

Team Letter: ____________________

Date: ____________________

Total Kit Value

$207.95

Total Amount Owed

$207.95

GTA Signature: ____________________

Student Signatures: ____________________ **Email Addresses:** ____________________

____________________ ____________________

____________________ ____________________

____________________ ____________________

Advance Energy Vehicle (AEV) Kit Label

If this kit is found please return to the Engineering Education Innovation Center (EEIC) located in room 244 Hitchcock Hall

OR

Contact:

Group Letter/Name:____________________

Name:____________________ E-mail:___________________ Phone:_____________

Name:____________________ E-mail:___________________ Phone:_____________

Name:____________________ E-mail:___________________ Phone:_____________

Name:____________________ E-mail:___________________ Phone:_____________

Name:____________________ E-mail:___________________ Phone:_____________

Policy Regarding Student Responsibility and Safety

The AEV kit that the team is receiving for this semester's Design-Build Project is the team's responsibility to maintain and use for the duration of the semester. The team will need it in every class and/or lab period as specified in the course schedule and/or as directed by the instructor. During the term: 1) Inventory the kit when it is issued to the team; 2) Use the parts list that is provided with the kit; 3) inventory the kit at the end of the semester.

There are several expensive items in this kit and if they are missing or damaged then we reserve the right to charge the team for the replacement cost. If the team (or a team member) loses the kit, or the kit is stolen or completely damaged while in your possession, then the instructor reserves the right to charge the team for the replacement cost of the AEV kit. Likewise, there are several expensive components that the team will use in the room but not take with after the lab's completion. Failure to return these components or causing damage to these components will result in a charge to replace them.

<u>The team's grade for the course will also be withheld until the team has paid for the kits or kit parts</u>.The team should be extremely cautious when using metal pieces around this the Arduino controller. The device can be shorted and damaged, and while difficult, it is possible to short the battery connectors where they attach to the board, which could create significant damage to both the board and the battery. Please remember that LiPo batteries hold a significant amount of energy and any short circuit will instantly release that energy. If the battery is damaged, please bring it to the instructor's attention.

By signing below, each team member accepts equal responsibility for the use of the AEV kit and any equipment or components issued to the team for the current semester, and agrees to abide by all safety guidelines.

___________________________	___________________________	________________
Student Signature	Printed Name	Date
___________________________	___________________________	________________
Student Signature	Printed Name	Date
___________________________	___________________________	________________
Student Signature	Printed Name	Date
___________________________	___________________________	________________
Student Signature	Printed Name	Date
___________________________	___________________________	________________
Student Signature	Printed Name	Date